US009119110B2

(12) **United States Patent**
Merlin et al.

(10) **Patent No.: US 9,119,110 B2**
(45) **Date of Patent: Aug. 25, 2015**

(54) **REQUEST TO SEND (RTS) AND CLEAR TO SEND (CTS) FOR MULTICHANNEL OPERATIONS**

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(73) Assignee: **QUALCOMM, Incorporated**, San Diego, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 744 days.

(21) Appl. No.: **13/239,206**

(22) Filed: **Sep. 21, 2011**

(65) **Prior Publication Data**

US 2012/0243485 A1 Sep. 27, 2012

Related U.S. Application Data

(60) Provisional application No. 61/385,462, filed on Sep. 22, 2010, provisional application No. 61/387,744, filed on Sep. 29, 2010, provisional application No. 61/392,456, filed on Oct. 12, 2010.

(51) **Int. Cl.**

H04W 4/00	(2009.01)
H04W 28/20	(2009.01)
H04W 28/10	(2009.01)
H04W 28/16	(2009.01)
H04W 72/04	(2009.01)
H04W 74/08	(2009.01)

(52) **U.S. Cl.**

CPC ***H04W 28/20*** (2013.01); *H04W 28/10* (2013.01); *H04W 28/16* (2013.01); *H04W 72/04* (2013.01); *H04W 74/0816* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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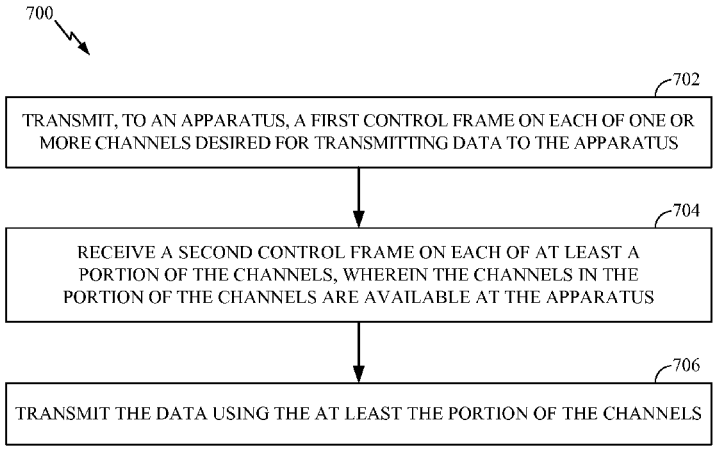
Primary Examiner — Bob Phunkulh

(74) *Attorney, Agent, or Firm* — Dang M. Vo

(57) **ABSTRACT**

Certain aspects of the present disclosure provide techniques and apparatus for signaling the bandwidth to be used for wireless communications using an RTS/CTS (Request to Send/Clear to Send) frame exchange, providing for bandwidths of at least 20 MHz, 40 MHz, 80 MHz, 160 MHz, or higher. This exchange of bandwidth information may be performed implicitly—by determining the channels in which the RTS/CTS frames are actually sent—or explicitly. In addition to this bandwidth information exchange, aspects of the present disclosure may also allow for Network Allocation Vector (NAV) protection in multiple channels. In this manner, the wireless medium may be reserved, and the transmission may be protected from hidden nodes.

103 Claims, 15 Drawing Sheets



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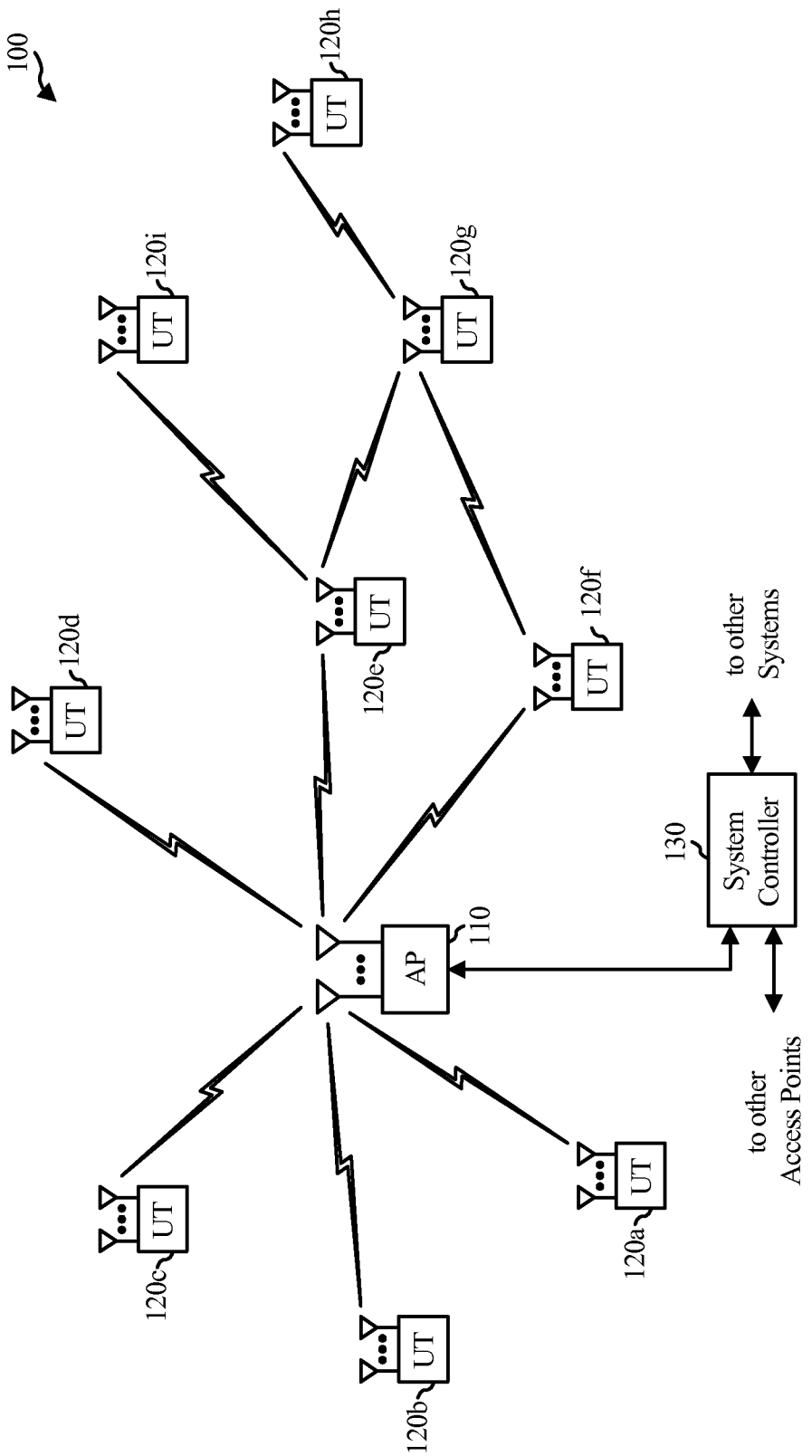
100
UT
120h
UT
120i
UT
120g
UT
120d
UT
120e
UT
120f
to other Systems
130
System Controller
AP
110
120c
UT
120b
UT
120a
UT
to other Access Points

FIG. 1

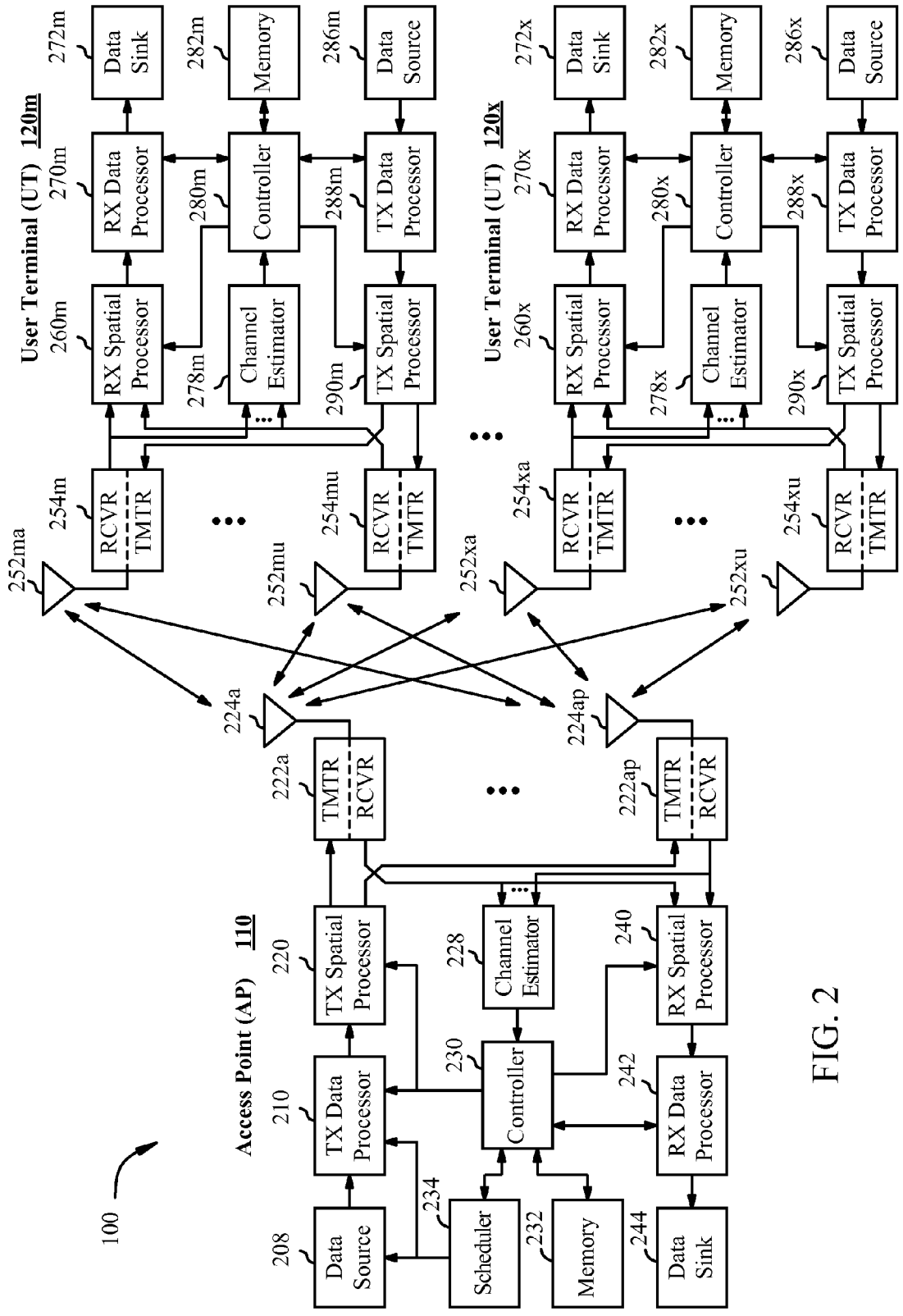
100
Access Point (AP) 110
208 Data Source
210 TX Data Processor
220 TX Spatial Processor
222a TMTR RCVR
222ap TMTR RCVR
224a
224ap
228 Channel Estimator
230 Controller
232 Memory
234 Scheduler
240 RX Spatial Processor
242 RX Data Processor
244 Data Sink
252ma
252mu
252xa
252xu
User Terminal (UT) 120m
254m RCVR TMTR
254mu RCVR TMTR
260m RX Spatial Processor
270m RX Data Processor
272m Data Sink
278m Channel Estimator
280m Controller
282m Memory
288m TX Data Processor
290m TX Spatial Processor
286m Data Source
User Terminal (UT) 120x
254xa RCVR TMTR
254xu RCVR TMTR
260x RX Spatial Processor
270x RX Data Processor
272x Data Sink
278x Channel Estimator
280x Controller
282x Memory
288x TX Data Processor
290x TX Spatial Processor
286x Data Source

FIG. 2

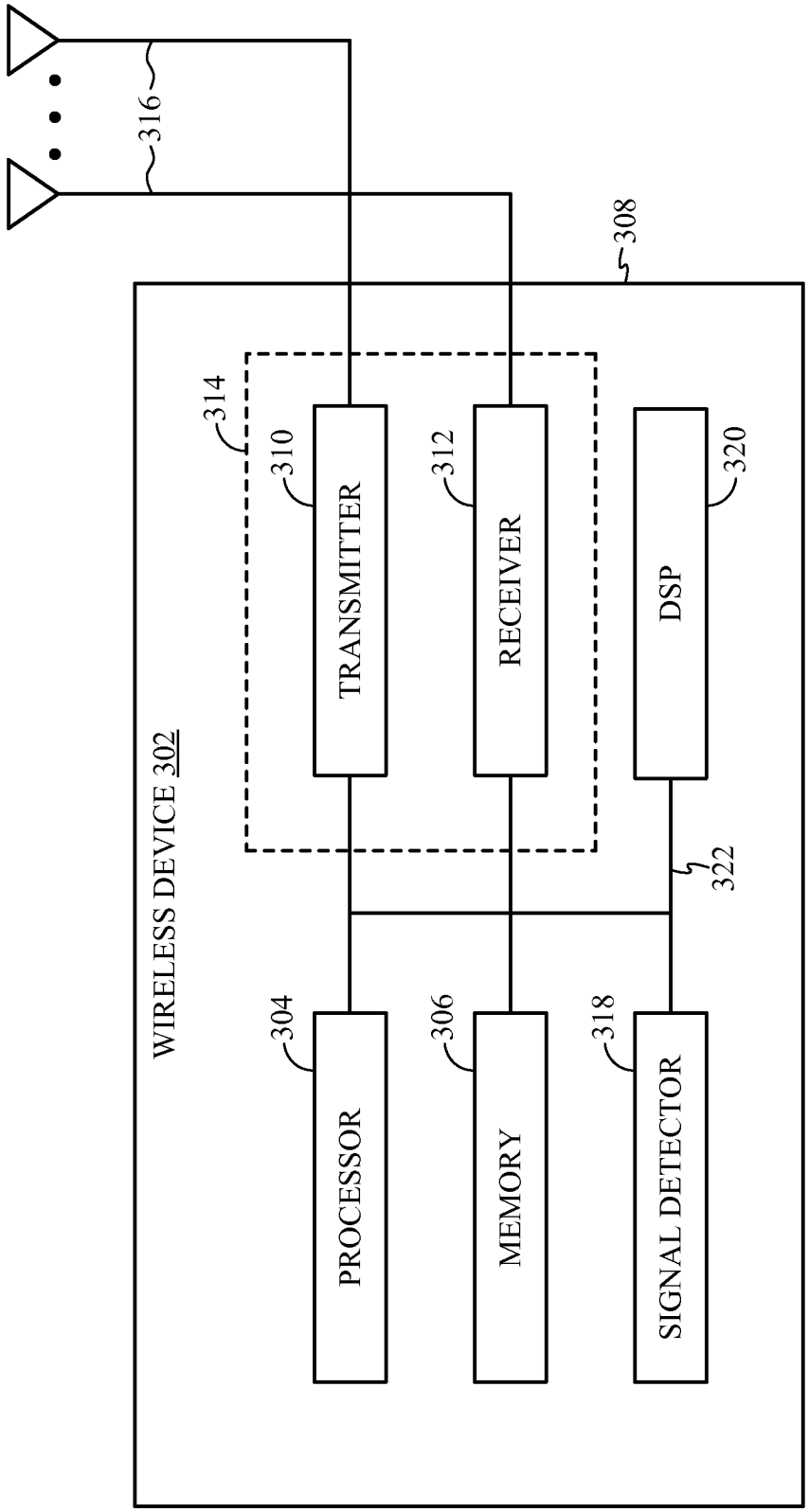
316
308
314
310
TRANSMITTER
312
RECEIVER
320
DSP
WIRELESS DEVICE 302
322
304
PROCESSOR
306
MEMORY
318
SIGNAL DETECTOR

FIG. 3

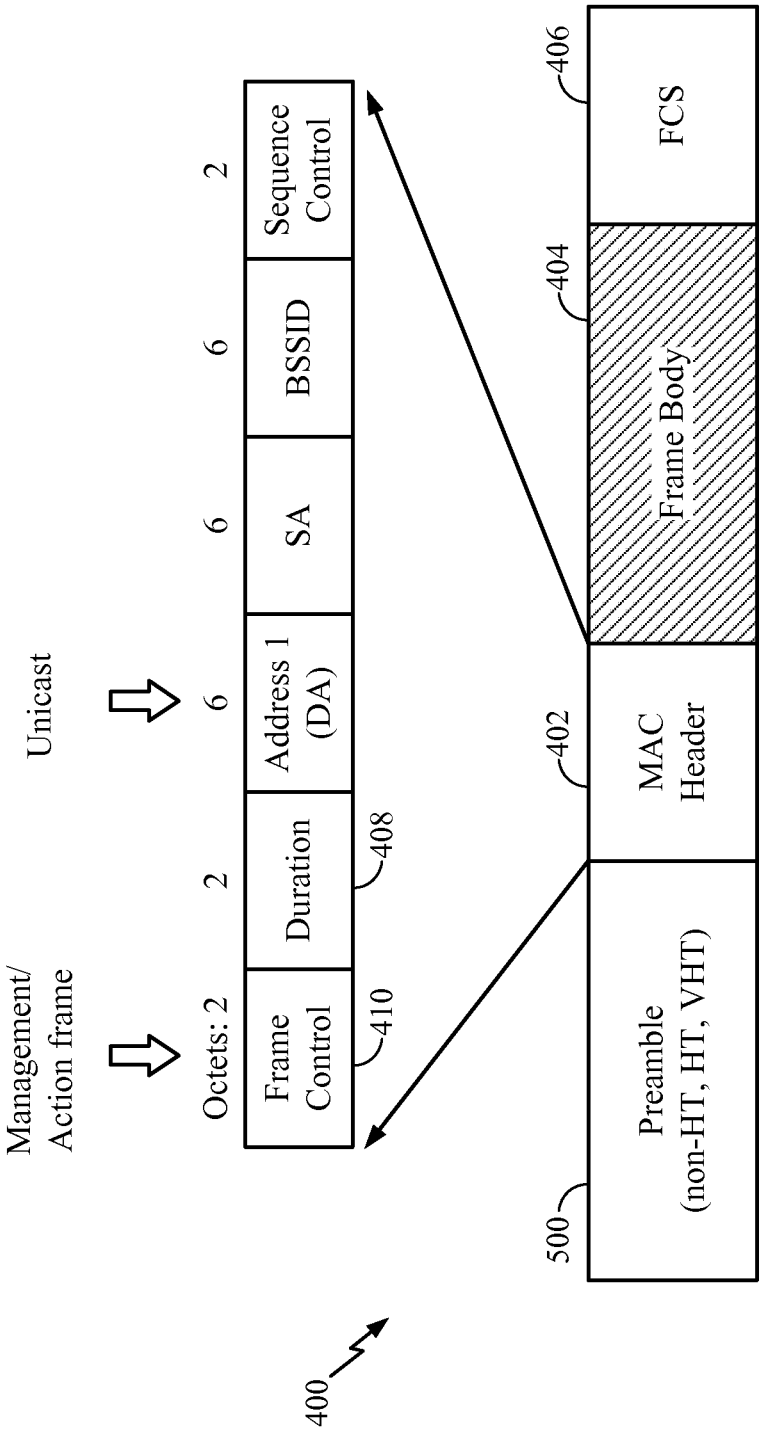
400
Management/
Action frame
Unicast
Octets: 2
2
6
6
6
2
Frame Control
Duration
Address 1 (DA)
SA
BSSID
Sequence Control
410
408
Preamble (non-HT, HT, VHT)
MAC Header
Frame Body
FCS
500
402
404
406

FIG. 4

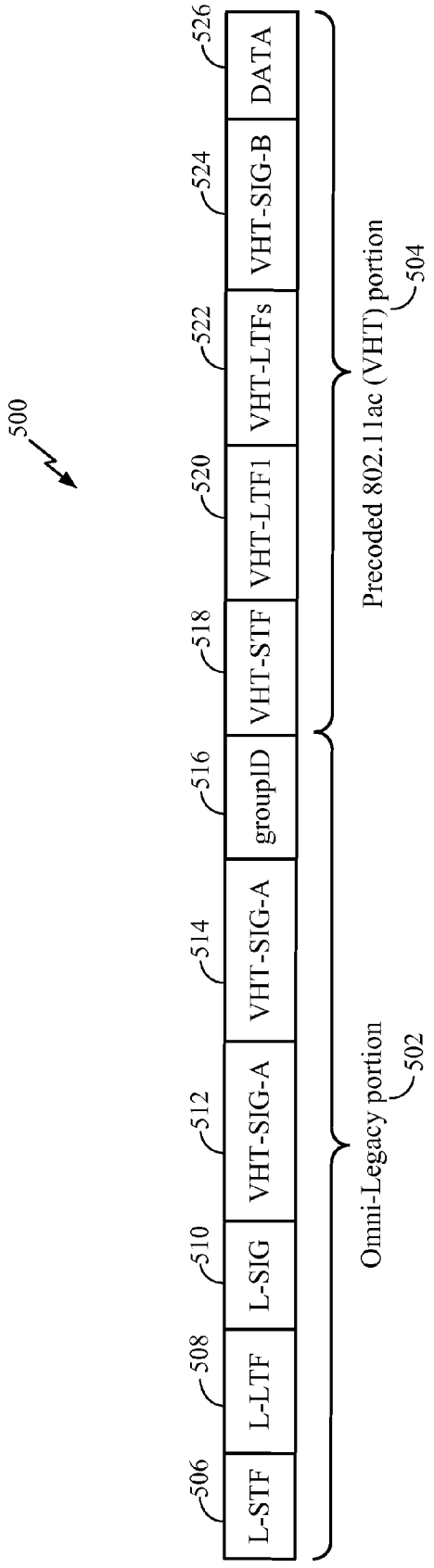
500
L-STF
506
L-LTF
508
L-SIG
510
VHT-SIG-A
512
VHT-SIG-A
514
groupID
516
VHT-STF
518
VHT-LTF1
520
VHT-LTFs
522
VHT-SIG-B
524
DATA
526
Omni-Legacy portion
502
Precoded 802.11ac (VHT) portion
504

FIG. 5

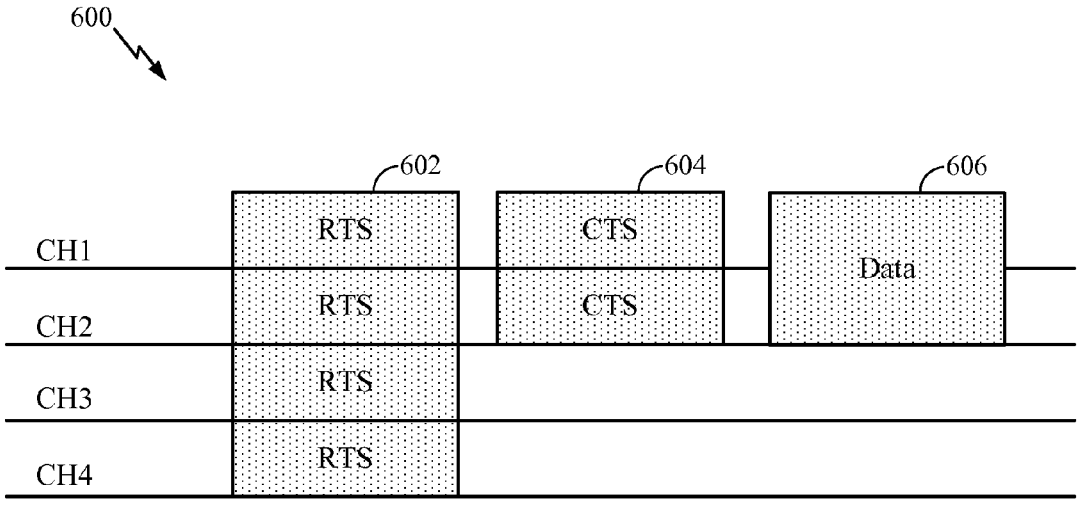

FIG. 6

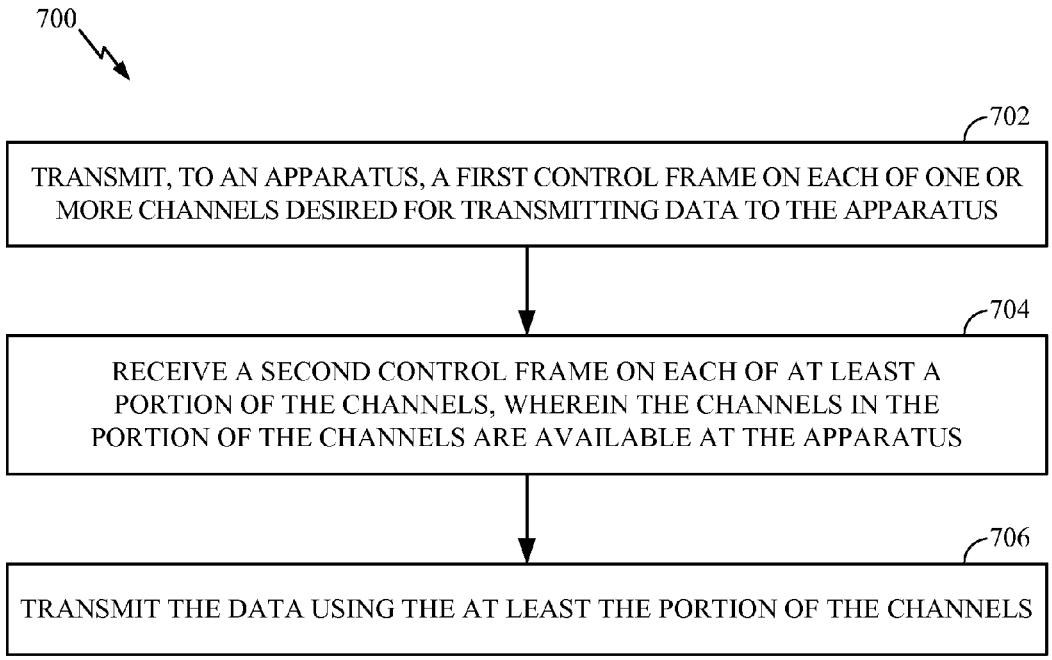
700
702
TRANSMIT, TO AN APPARATUS, A FIRST CONTROL FRAME ON EACH OF ONE OR MORE CHANNELS DESIRED FOR TRANSMITTING DATA TO THE APPARATUS
704
RECEIVE A SECOND CONTROL FRAME ON EACH OF AT LEAST A PORTION OF THE CHANNELS, WHEREIN THE CHANNELS IN THE PORTION OF THE CHANNELS ARE AVAILABLE AT THE APPARATUS
706
TRANSMIT THE DATA USING THE AT LEAST THE PORTION OF THE CHANNELS

FIG. 7

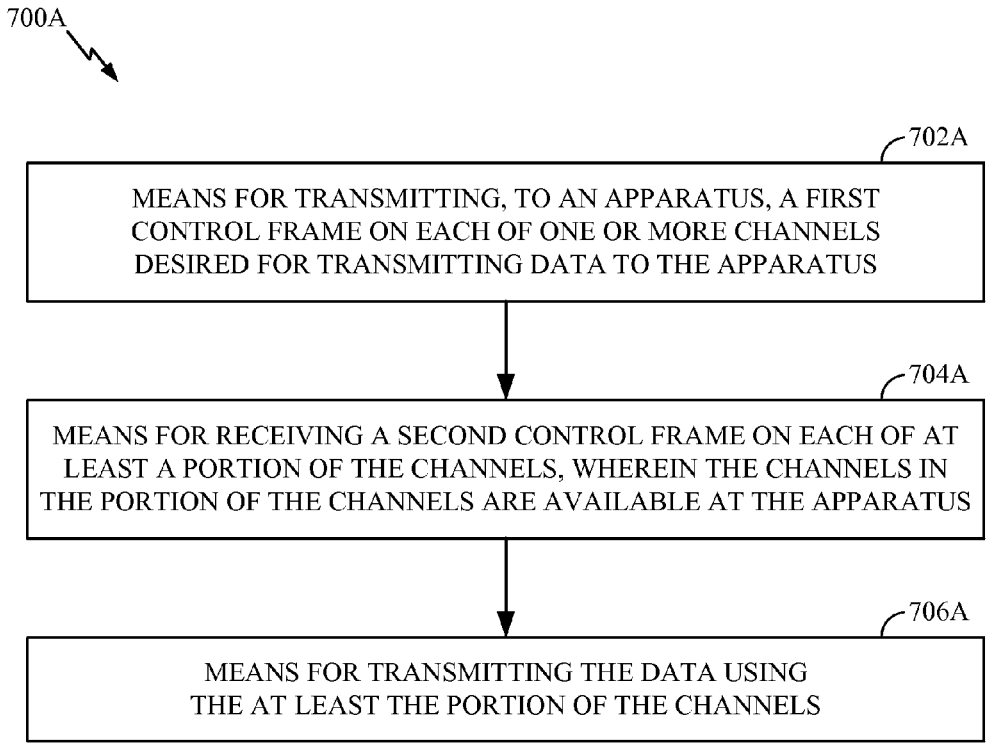
700A
702A
MEANS FOR TRANSMITTING, TO AN APPARATUS, A FIRST CONTROL FRAME ON EACH OF ONE OR MORE CHANNELS DESIRED FOR TRANSMITTING DATA TO THE APPARATUS
704A
MEANS FOR RECEIVING A SECOND CONTROL FRAME ON EACH OF AT LEAST A PORTION OF THE CHANNELS, WHEREIN THE CHANNELS IN THE PORTION OF THE CHANNELS ARE AVAILABLE AT THE APPARATUS
706A
MEANS FOR TRANSMITTING THE DATA USING THE AT LEAST THE PORTION OF THE CHANNELS

FIG. 7A

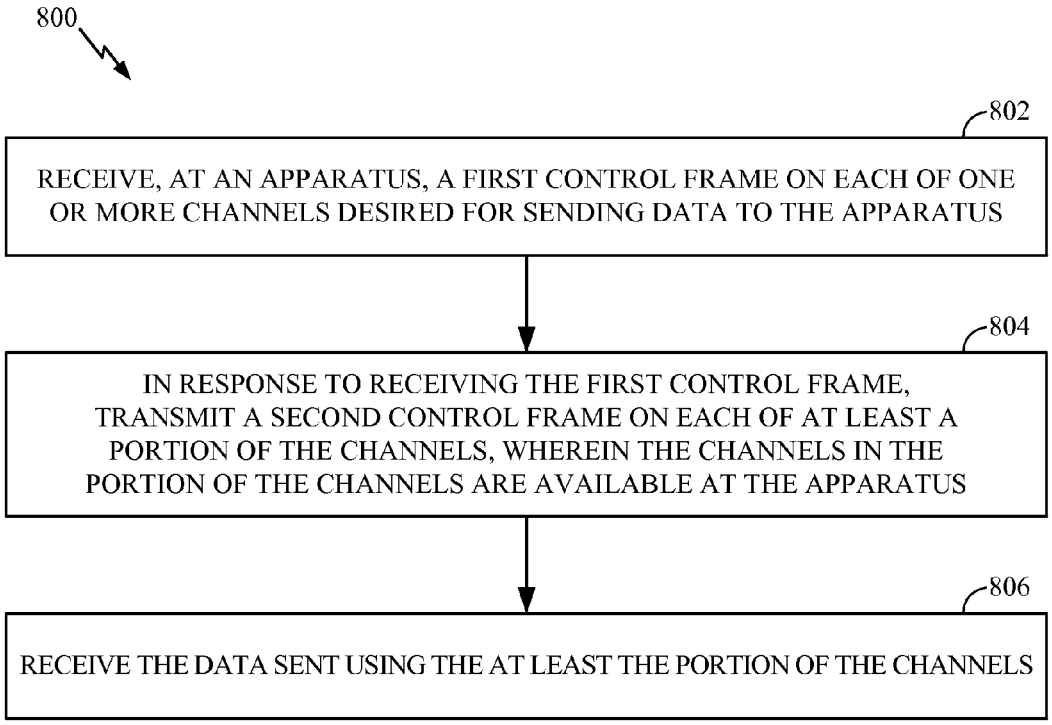
800
802
RECEIVE, AT AN APPARATUS, A FIRST CONTROL FRAME ON EACH OF ONE OR MORE CHANNELS DESIRED FOR SENDING DATA TO THE APPARATUS
804
IN RESPONSE TO RECEIVING THE FIRST CONTROL FRAME, TRANSMIT A SECOND CONTROL FRAME ON EACH OF AT LEAST A PORTION OF THE CHANNELS, WHEREIN THE CHANNELS IN THE PORTION OF THE CHANNELS ARE AVAILABLE AT THE APPARATUS
806
RECEIVE THE DATA SENT USING THE AT LEAST THE PORTION OF THE CHANNELS

FIG. 8

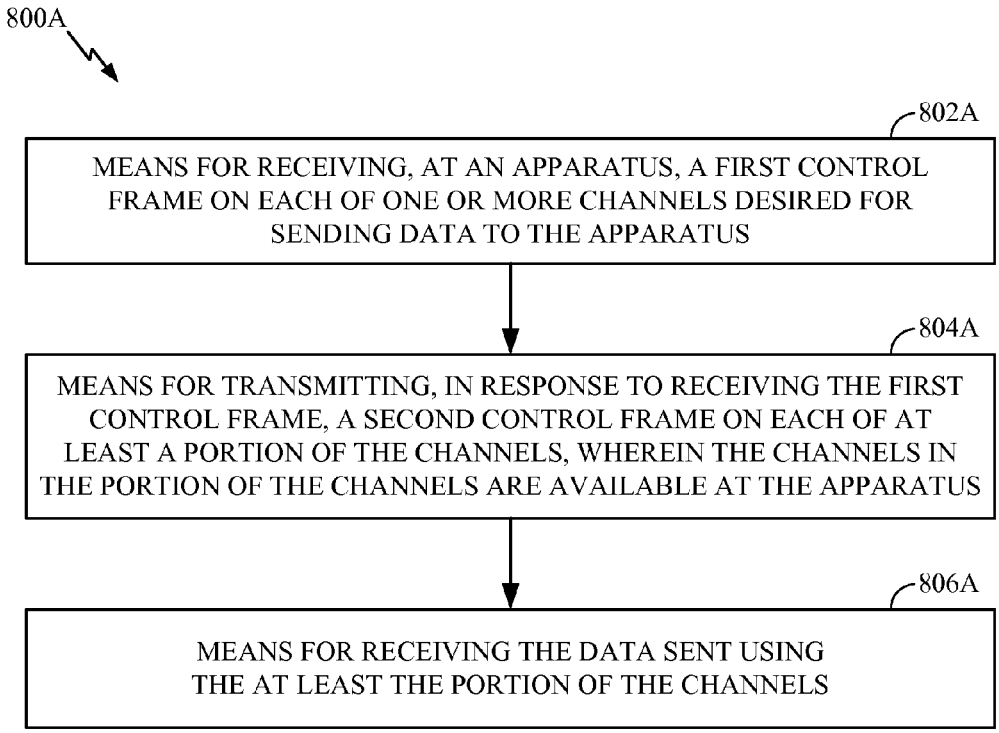
800A
802A
MEANS FOR RECEIVING, AT AN APPARATUS, A FIRST CONTROL FRAME ON EACH OF ONE OR MORE CHANNELS DESIRED FOR SENDING DATA TO THE APPARATUS
804A
MEANS FOR TRANSMITTING, IN RESPONSE TO RECEIVING THE FIRST CONTROL FRAME, A SECOND CONTROL FRAME ON EACH OF AT LEAST A PORTION OF THE CHANNELS, WHEREIN THE CHANNELS IN THE PORTION OF THE CHANNELS ARE AVAILABLE AT THE APPARATUS
806A
MEANS FOR RECEIVING THE DATA SENT USING THE AT LEAST THE PORTION OF THE CHANNELS

FIG. 8A

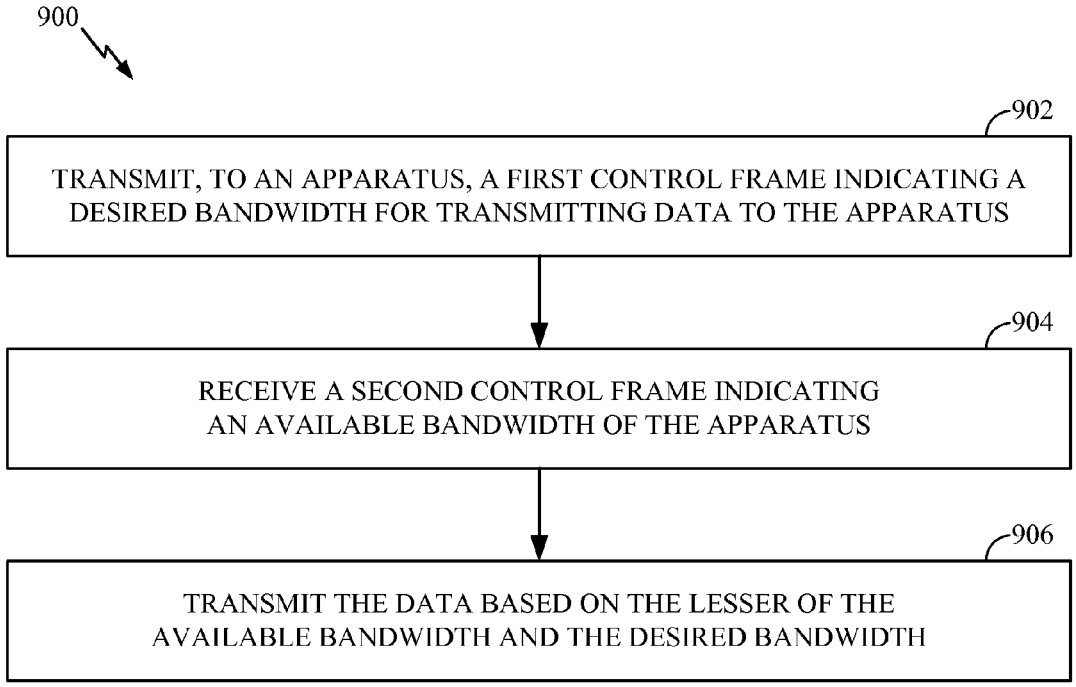
900
902
TRANSMIT, TO AN APPARATUS, A FIRST CONTROL FRAME INDICATING A DESIRED BANDWIDTH FOR TRANSMITTING DATA TO THE APPARATUS
904
RECEIVE A SECOND CONTROL FRAME INDICATING AN AVAILABLE BANDWIDTH OF THE APPARATUS
906
TRANSMIT THE DATA BASED ON THE LESSER OF THE AVAILABLE BANDWIDTH AND THE DESIRED BANDWIDTH

FIG. 9

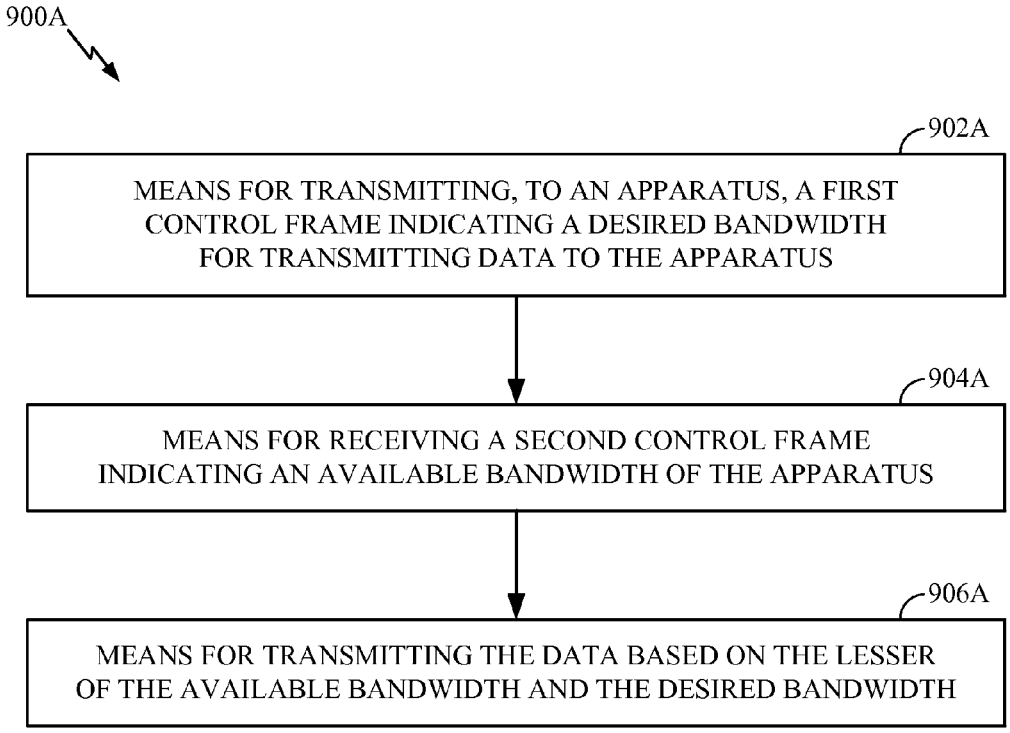
900A
902A
MEANS FOR TRANSMITTING, TO AN APPARATUS, A FIRST CONTROL FRAME INDICATING A DESIRED BANDWIDTH FOR TRANSMITTING DATA TO THE APPARATUS
904A
MEANS FOR RECEIVING A SECOND CONTROL FRAME INDICATING AN AVAILABLE BANDWIDTH OF THE APPARATUS
906A
MEANS FOR TRANSMITTING THE DATA BASED ON THE LESSER OF THE AVAILABLE BANDWIDTH AND THE DESIRED BANDWIDTH

FIG. 9A

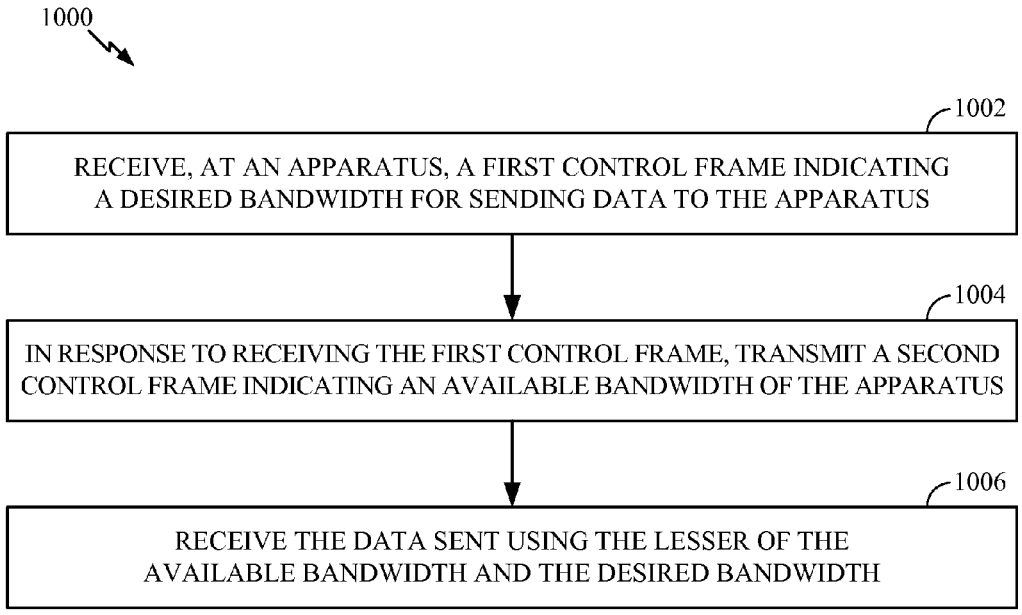

FIG. 10

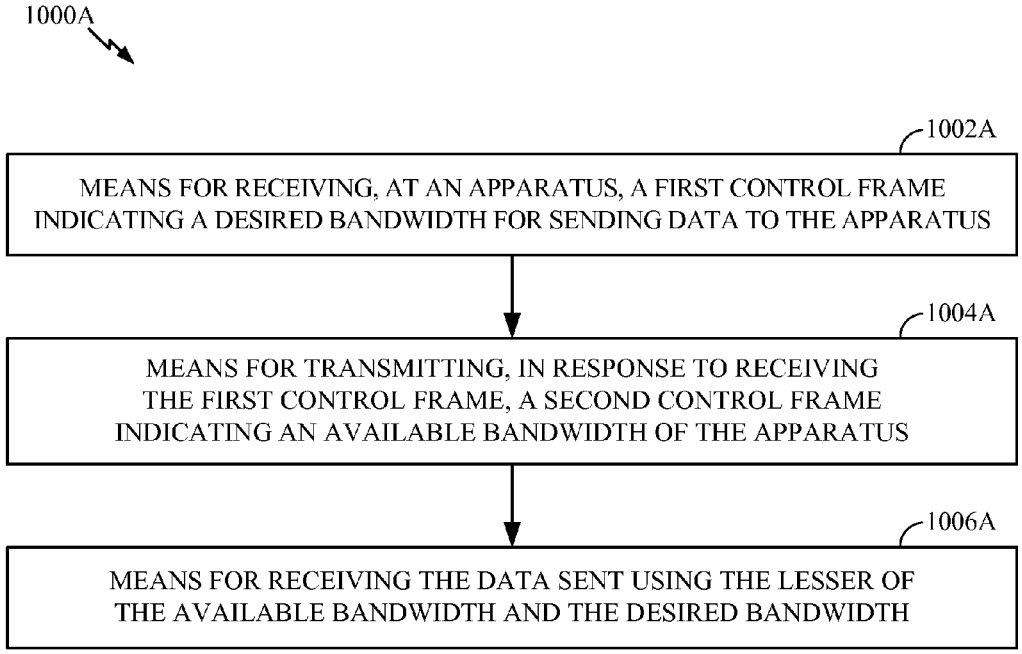

FIG. 10A

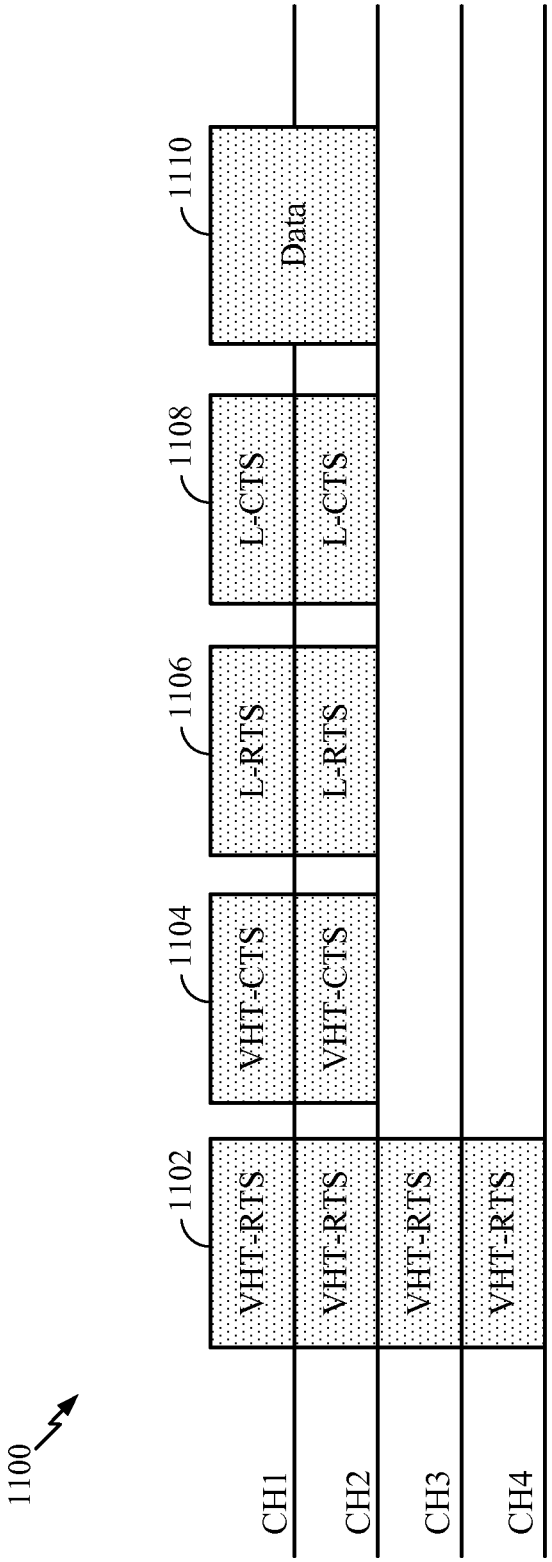
1100
CH1
CH2
CH3
CH4
1102
VHT-RTS
VHT-RTS
VHT-RTS
VHT-RTS
1104
VHT-CTS
VHT-CTS
1106
L-RTS
L-RTS
1108
L-CTS
L-CTS
1110
Data

FIG. 11

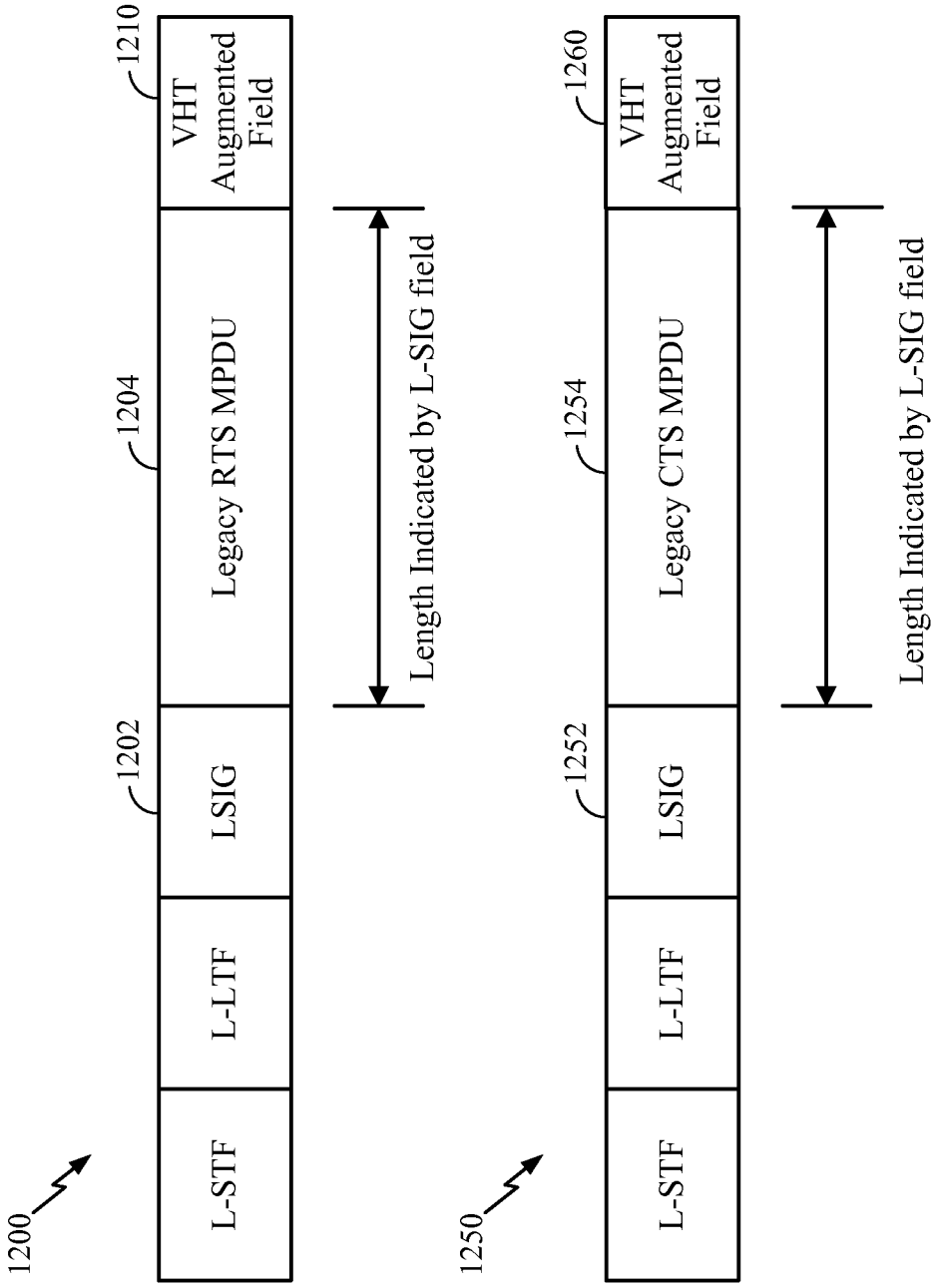
1200
L-STF
L-LTF
LSIG
1202
Legacy RTS MPDU
1204
VHT Augmented Field
1210
Length Indicated by L-SIG field
1250
L-STF
L-LTF
LSIG
1252
Legacy CTS MPDU
1254
VHT Augmented Field
1260
Length Indicated by L-SIG field

FIG. 12

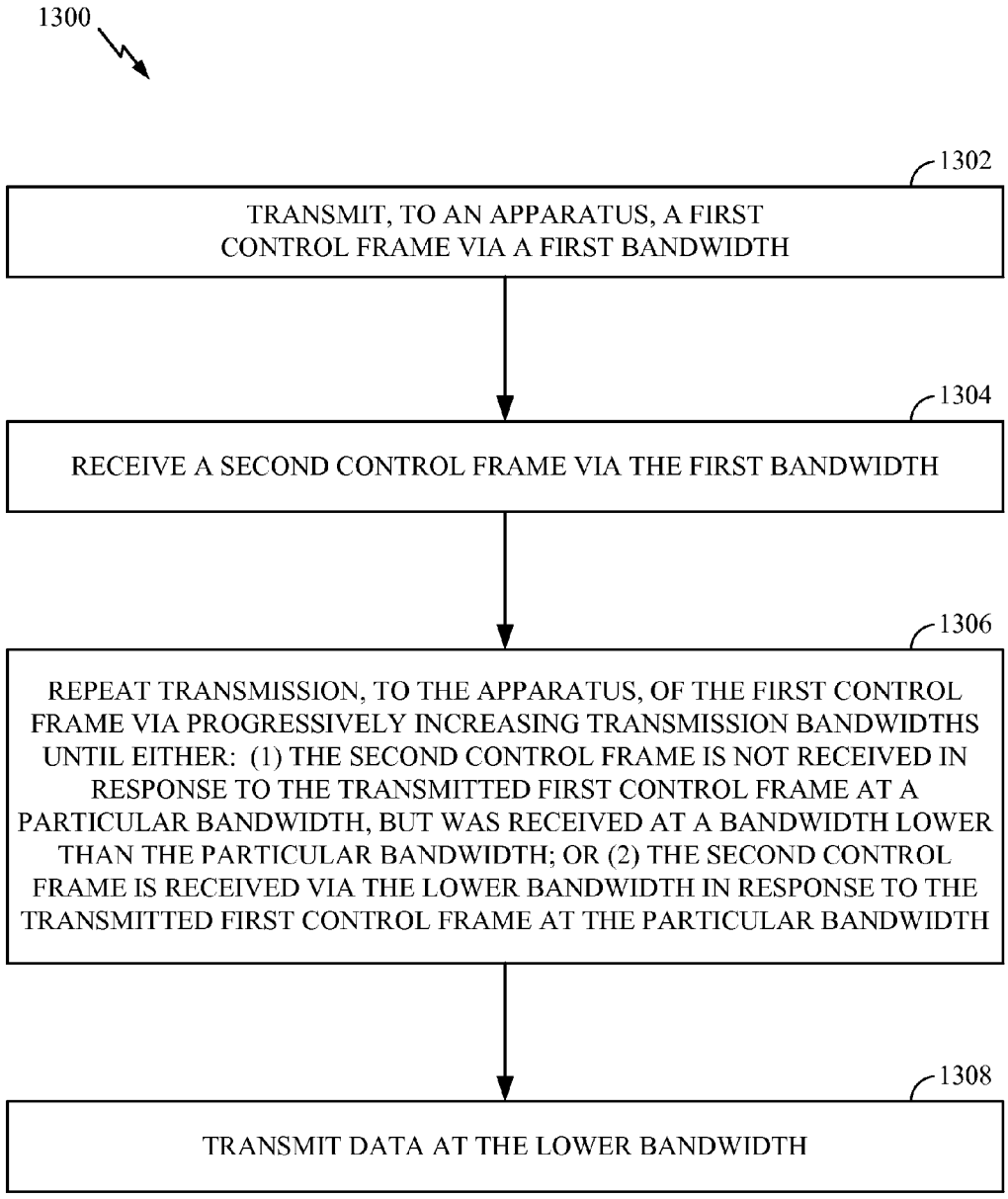
1300
1302
TRANSMIT, TO AN APPARATUS, A FIRST CONTROL FRAME VIA A FIRST BANDWIDTH
1304
RECEIVE A SECOND CONTROL FRAME VIA THE FIRST BANDWIDTH
1306
REPEAT TRANSMISSION, TO THE APPARATUS, OF THE FIRST CONTROL FRAME VIA PROGRESSIVELY INCREASING TRANSMISSION BANDWIDTHS UNTIL EITHER: (1) THE SECOND CONTROL FRAME IS NOT RECEIVED IN RESPONSE TO THE TRANSMITTED FIRST CONTROL FRAME AT A PARTICULAR BANDWIDTH, BUT WAS RECEIVED AT A BANDWIDTH LOWER THAN THE PARTICULAR BANDWIDTH; OR (2) THE SECOND CONTROL FRAME IS RECEIVED VIA THE LOWER BANDWIDTH IN RESPONSE TO THE TRANSMITTED FIRST CONTROL FRAME AT THE PARTICULAR BANDWIDTH
1308
TRANSMIT DATA AT THE LOWER BANDWIDTH

FIG. 13

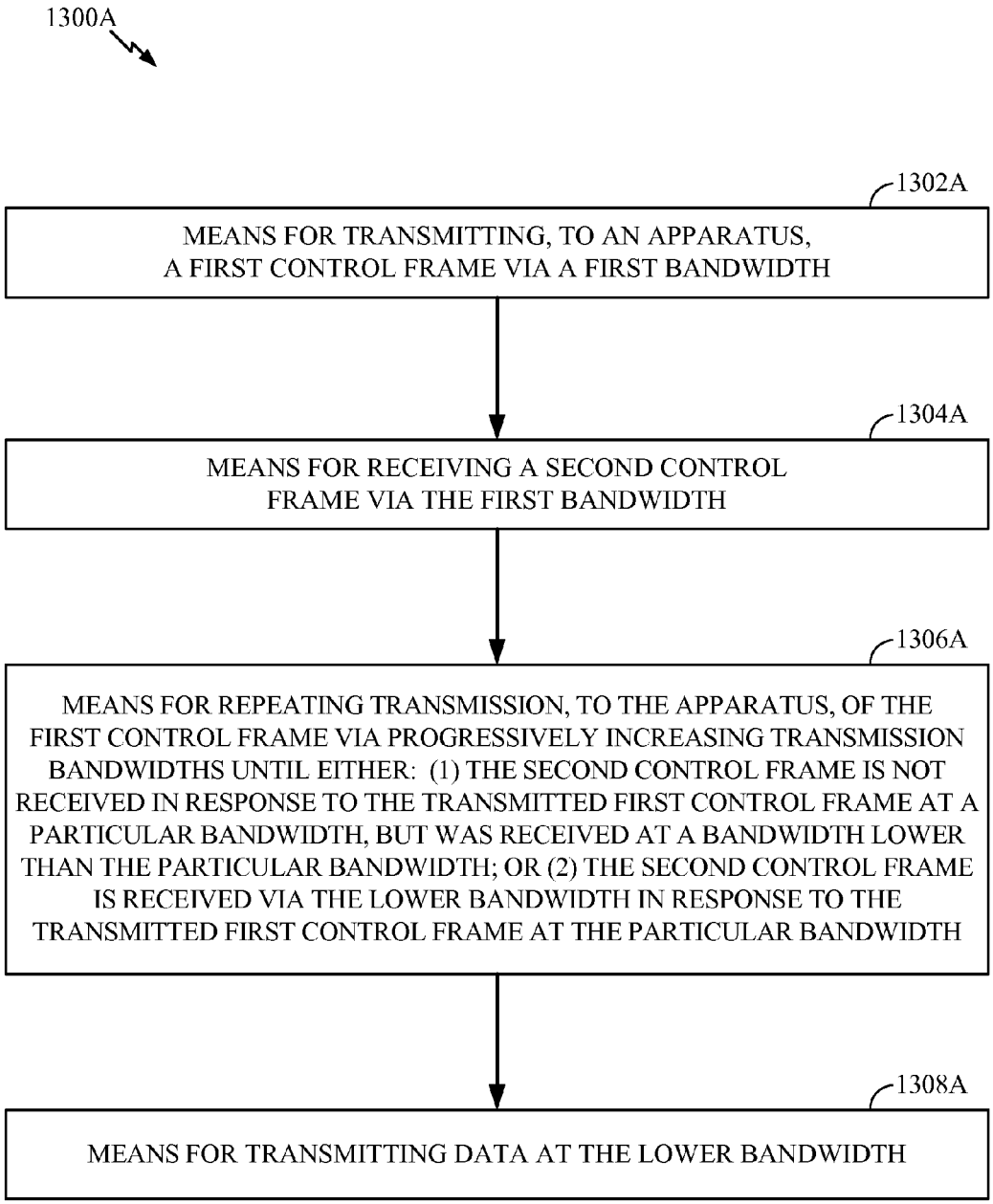
1300A
1302A
MEANS FOR TRANSMITTING, TO AN APPARATUS, A FIRST CONTROL FRAME VIA A FIRST BANDWIDTH
1304A
MEANS FOR RECEIVING A SECOND CONTROL FRAME VIA THE FIRST BANDWIDTH
1306A
MEANS FOR REPEATING TRANSMISSION, TO THE APPARATUS, OF THE FIRST CONTROL FRAME VIA PROGRESSIVELY INCREASING TRANSMISSION BANDWIDTHS UNTIL EITHER: (1) THE SECOND CONTROL FRAME IS NOT RECEIVED IN RESPONSE TO THE TRANSMITTED FIRST CONTROL FRAME AT A PARTICULAR BANDWIDTH, BUT WAS RECEIVED AT A BANDWIDTH LOWER THAN THE PARTICULAR BANDWIDTH; OR (2) THE SECOND CONTROL FRAME IS RECEIVED VIA THE LOWER BANDWIDTH IN RESPONSE TO THE TRANSMITTED FIRST CONTROL FRAME AT THE PARTICULAR BANDWIDTH
1308A
MEANS FOR TRANSMITTING DATA AT THE LOWER BANDWIDTH

FIG. 13A

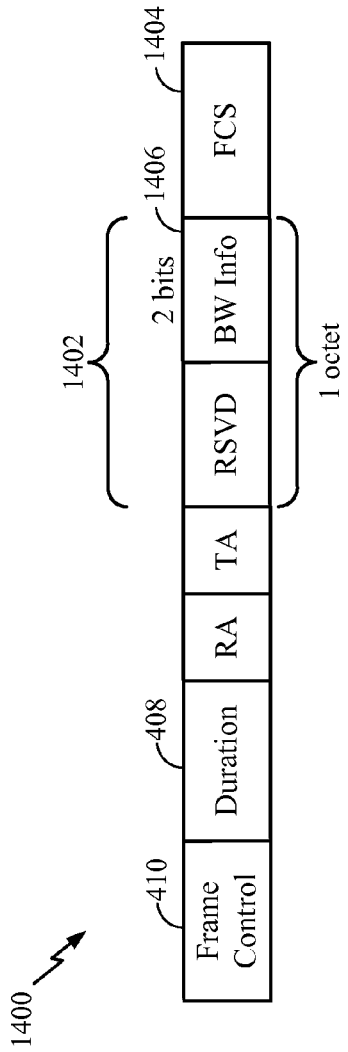
1400
Frame Control
410
Duration
408
RA
TA
RSVD
2 bits
BW Info
1406
FCS
1404
1402
1 octet

FIG. 14

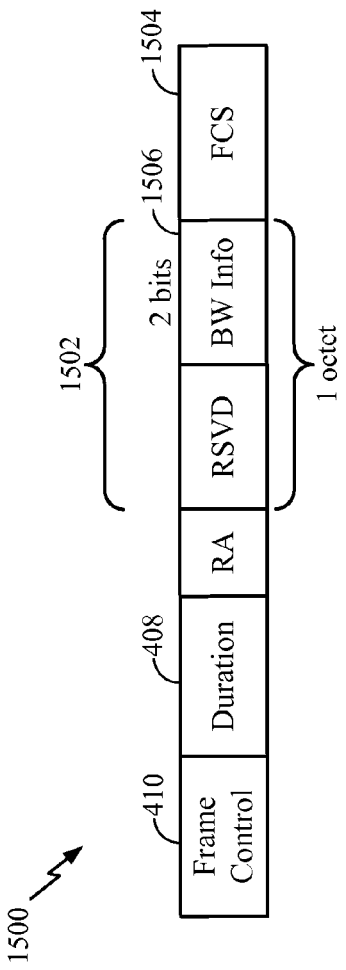
1500
Frame Control
410
Duration
408
RA
RSVD
2 bits
BW Info
1506
FCS
1504
1502
1 octet

FIG. 15

REQUEST TO SEND (RTS) AND CLEAR TO SEND (CTS) FOR MULTICHANNEL OPERATIONS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims benefit of U.S. Provisional Patent Application Ser. No. 61/385,462, filed Sep. 22, 2010, U.S. Provisional Patent Application Ser. No. 61/387,744, filed Sep. 29, 2010, and U.S. Provisional Patent Application Ser. No. 61/392,456, filed Oct. 12, 2010, all of which are herein incorporated by reference.

BACKGROUND

1. Field

Certain aspects of the present disclosure generally relate to wireless communications and, more particularly, to exchanging bandwidth information between a transmitting entity and a receiving entity to determine the bandwidth to be used between the two entities for transmitting data.

2. Background

In order to address the issue of increasing bandwidth requirements demanded for wireless communications systems, different schemes are being developed to allow multiple user terminals to communicate with a single access point by sharing the channel resources while achieving high data throughputs. Multiple Input Multiple Output (MIMO) technology represents one such approach that has recently emerged as a popular technique for next generation communication systems. MIMO technology has been adopted in several emerging wireless communications standards such as the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standard. The IEEE 802.11 denotes a set of Wireless Local Area Network (WLAN) air interface standards developed by the IEEE 802.11 committee for short-range communications (e.g., tens of meters to a few hundred meters).

A MIMO system employs multiple (N_T) transmit antennas and multiple (N_R) receive antennas for data transmission. A MIMO channel formed by the N_T transmit and N_R receive antennas may be decomposed into N_S independent channels, which are also referred to as spatial channels, where $N_S \leq \min\{N_T, N_R\}$. Each of the N_S independent channels corresponds to a dimension. The MIMO system can provide improved performance (e.g., higher throughput and/or greater reliability) if the additional dimensionalities created by the multiple transmit and receive antennas are utilized.

In wireless networks with a single Access Point (AP) and multiple user stations (STAs), concurrent transmissions may occur on multiple channels toward different stations, both in the uplink and downlink direction. Many challenges are present in such systems.

SUMMARY

Certain aspects of the present disclosure generally relate to exchanging bandwidth information between a transmitting entity and a receiving entity via a control frame mechanism (e.g., an RTS/CTS mechanism) to determine the data-transmission bandwidth to be used between the two entities.

Certain aspects of the present disclosure provide a method for wireless communications. The method generally includes transmitting, to an apparatus, a first control frame indicating a desired bandwidth for transmitting data to the apparatus; receiving a second control frame indicating an available bandwidth of the apparatus; and transmitting the data based on the lesser of the available bandwidth and the desired bandwidth.

Certain aspects of the present disclosure provide an apparatus for wireless communications. The apparatus generally includes a transmitter configured to transmit, to another apparatus, a first control frame indicating a desired bandwidth for transmitting data to the other apparatus; and a receiver configured to receive a second control frame indicating an available bandwidth of the other apparatus, wherein the transmitter is further configured to transmit the data based on the lesser of the available bandwidth and the desired bandwidth.

Certain aspects of the present disclosure provide an apparatus for wireless communications. The apparatus generally includes means for transmitting, to another apparatus, a first control frame indicating a desired bandwidth for transmitting data to the other apparatus; and means for receiving a second control frame indicating an available bandwidth of the other apparatus, wherein the means for transmitting is further configured to transmit the data based on the lesser of the available bandwidth and the desired bandwidth.

Certain aspects of the present disclosure provide a computer-program product for wireless communications. The computer-program product generally includes a computer-readable medium having instructions executable to transmit, to an apparatus, a first control frame indicating a desired bandwidth for transmitting data to the apparatus; to receive a second control frame indicating an available bandwidth of the apparatus; and to transmit the data based on the lesser of the available bandwidth and the desired bandwidth.

Certain aspects of the present disclosure provide an access point. The access point generally includes at least one antenna; a transmitter configured to transmit, to an apparatus via the at least one antenna, a first control frame indicating a desired bandwidth for transmitting data to the apparatus; and a receiver configured to receive a second control frame indicating an available bandwidth of the apparatus, wherein the transmitter is further configured to transmit the data based on the lesser of the available bandwidth and the desired bandwidth.

Certain aspects of the present disclosure provide a method for wireless communications. The method generally includes receiving, at an apparatus, a first control frame indicating a desired bandwidth for sending data to the apparatus; in response to receiving the first control frame, transmitting a second control frame indicating an available bandwidth of the apparatus; and receiving the data sent using the lesser of the available bandwidth and the desired bandwidth.

Certain aspects of the present disclosure provide an apparatus for wireless communications. The apparatus generally includes a receiver configured to receive a first control frame indicating a desired bandwidth for sending data to the apparatus; and a transmitter configured to transmit, in response to receiving the first control frame, a second control frame indicating an available bandwidth of the apparatus, wherein the receiver is further configured to receive the data sent using the lesser of the available bandwidth and the desired bandwidth.

Certain aspects of the present disclosure provide an apparatus for wireless communications. The apparatus generally includes means for receiving a first control frame indicating a desired bandwidth for sending data to the apparatus; and means for transmitting, in response to receiving the first control frame, a second control frame indicating an available bandwidth of the apparatus, wherein the means for receiving is further configured to receive the data sent using the lesser of the available bandwidth and the desired bandwidth.

Certain aspects of the present disclosure provide a computer-program product for wireless communications. The computer-program product generally includes a computer-readable medium having instructions executable to receive, at an apparatus, a first control frame indicating a desired bandwidth for sending data to the apparatus; to transmit, in response to receiving the first control frame, a second control frame indicating an available bandwidth of the apparatus; and to receive the data sent using the lesser of the available bandwidth and the desired bandwidth.

Certain aspects of the present disclosure provide a wireless node. The wireless node generally includes at least one antenna; a receiver configured to receive, via the at least one antenna, a first control frame indicating a desired bandwidth for sending data to the apparatus; and a transmitter configured to transmit, in response to receiving the first control frame, a second control frame indicating an available bandwidth of the apparatus, wherein the receiver is further configured to receive the data sent using the lesser of the available bandwidth and the desired bandwidth.

Certain aspects of the present disclosure provide a method for wireless communications. The method generally includes transmitting, to an apparatus, a first control frame on each of one or more channels desired for transmitting data to the apparatus; receiving a second control frame on each of at least a portion of the channels, wherein the channels in the portion of the channels are available at the apparatus; and transmitting the data using the at least the portion of the channels.

Certain aspects of the present disclosure provide an apparatus for wireless communications. The apparatus generally includes a transmitter configured to transmit, to another apparatus, a first control frame on each of one or more channels desired for transmitting data to the other apparatus; and a receiver configured to receive a second control frame on each of at least a portion of the channels, wherein the channels in the portion of the channels are available at the other apparatus and wherein the transmitter is further configured to transmit the data using the at least the portion of the channels.

Certain aspects of the present disclosure provide an apparatus for wireless communications. The apparatus generally includes means for transmitting, to another apparatus, a first control frame on each of one or more channels desired for transmitting data to the other apparatus; means for receiving a second control frame on each of at least a portion of the channels, wherein the channels in the portion of the channels are available at the other apparatus and wherein the means for transmitting is further configured to transmit the data using the at least the portion of the channels.

Certain aspects of the present disclosure provide a computer-program product for wireless communications. The computer-program product generally includes a computer-readable medium having instructions executable to transmit, to an apparatus, a first control frame on each of one or more channels desired for transmitting data to the apparatus; to receive a second control frame on each of at least a portion of the channels, wherein the channels in the portion of the channels are available at the apparatus; and to transmit the data using the at least the portion of the channels.

Certain aspects of the present disclosure provide an access point. The access point generally includes at least one antenna; a transmitter configured to transmit, to an apparatus via the at least one antenna, a first control frame on each of one or more channels desired for transmitting data to the apparatus; and a receiver configured to receive a second control frame on each of at least a portion of the channels, wherein the channels in the portion of the channels are available at the apparatus and wherein the transmitter is further configured to transmit the data using the at least the portion of the channels.

Certain aspects of the present disclosure provide a method for wireless communications. The method generally includes receiving, at an apparatus, a first control frame on each of one or more channels desired for sending data to the apparatus; in response to receiving the first control frame on each of the channels, transmitting a second control frame on each of at least a portion of the channels, wherein the channels in the portion of the channels are available at the apparatus; and receiving the data sent using the at least the portion of the channels.

Certain aspects of the present disclosure provide an apparatus for wireless communications. The apparatus generally includes a receiver configured to receive a first control frame on each of one or more channels desired for sending data to the apparatus; and a transmitter configured to transmit, in response to receiving the first control frame on each of the channels, a second control frame on each of at least a portion of the channels, wherein the channels in the portion of the channels are available at the apparatus and wherein the receiver is further configured to receive the data sent using the at least the portion of the channels.

Certain aspects of the present disclosure provide an apparatus for wireless communications. The apparatus generally includes means for receiving a first control frame on each of one or more channels desired for sending data to the apparatus; and means for transmitting, in response to receiving the first control frame on each of the channels, a second control frame on each of at least a portion of the channels, wherein the channels in the portion of the channels are available at the apparatus and wherein the means for receiving is further configured to receive the data sent using the at least the portion of the channels.

Certain aspects of the present disclosure provide a computer-program product for wireless communications. The computer-program product generally includes a computer-readable medium having instructions executable to receive, at an apparatus, a first control frame on each of one or more channels desired for sending data to the apparatus; to transmit, in response to receiving the first control frame on each of the channels, a second control frame on each of at least a portion of the channels, wherein the channels in the portion of the channels are available at the apparatus; and to receive the data sent using the at least the portion of the channels.

Certain aspects of the present disclosure provide a wireless node. The wireless node generally includes at least one antenna; a receiver configured to receive, via the at least one antenna, a first control frame on each of one or more channels desired for sending data to the apparatus; and a transmitter configured to transmit, in response to receiving the first control frame on each of the channels, a second control frame on each of at least a portion of the channels, wherein the channels in the portion of the channels are available at the apparatus and wherein the receiver is further configured to receive the data sent using the at least the portion of the channels.

Certain aspects of the present disclosure provide a method for wireless communications. The method generally includes transmitting, to an apparatus, a first control frame via a first bandwidth; receiving a second control frame via the first bandwidth; repeating transmission, to the apparatus, of the first control frame via progressively increasing transmission bandwidths until either: (1) the second control frame is not received in response to the transmitted first control frame at a particular bandwidth, but was received at a bandwidth lower than the particular bandwidth; or (2) the second control frame

is received via the lower bandwidth in response to the transmitted first control frame at the particular bandwidth; and transmitting data at the lower bandwidth.

Certain aspects of the present disclosure provide an apparatus for wireless communications. The apparatus generally includes a transmitter configured to transmit, to another apparatus, a first control frame via a first bandwidth; and a receiver configured to receive a second control frame via the first bandwidth, wherein the transmitter is further configured to repeat transmission, to the other apparatus, of the first control frame via progressively increasing transmission bandwidths until either: (1) the second control frame is not received in response to the transmitted first control frame at a particular bandwidth, but was received at a bandwidth lower than the particular bandwidth; or (2) the second control frame is received via the lower bandwidth in response to the transmitted first control frame at the particular bandwidth; wherein the transmitter is further configured to transmit data at the lower bandwidth.

Certain aspects of the present disclosure provide an apparatus for wireless communications. The apparatus generally includes means for transmitting, to another apparatus, a first control frame via a first bandwidth; means for receiving a second control frame via the first bandwidth, wherein the means for transmitting is configured to repeat transmission, to the other apparatus, of the first control frame via progressively increasing transmission bandwidths until either: (1) the second control frame is not received in response to the transmitted first control frame at a particular bandwidth, but was received at a bandwidth lower than the particular bandwidth; or (2) the second control frame is received via the lower bandwidth in response to the transmitted first control frame at the particular bandwidth; wherein the means for transmitting is configured to transmit data at the lower bandwidth.

Certain aspects of the present disclosure provide a computer-program product for wireless communications. The computer-program product generally includes a computer-readable medium having instructions executable to transmit, to an apparatus, a first control frame via a first bandwidth; to receive a second control frame via the first bandwidth; to repeat transmission, to the apparatus, of the first control frame via progressively increasing transmission bandwidths until either: (1) the second control frame is not received in response to the transmitted first control frame at a particular bandwidth, but was received at a bandwidth lower than the particular bandwidth; or (2) the second control frame is received via the lower bandwidth in response to the transmitted first control frame at the particular bandwidth; and to transmit data at the lower bandwidth.

Certain aspects of the present disclosure provide an access point. The access point generally includes at least one antenna; a transmitter configured to transmit, to an apparatus via the at least one antenna, a first control frame via a first bandwidth; and a receiver configured to receive a second control frame via the first bandwidth, wherein the transmitter is further configured to repeat transmission, to the other apparatus, of the first control frame via progressively increasing transmission bandwidths until either: (1) the second control frame is not received in response to the transmitted first control frame at a particular bandwidth, but was received at a bandwidth lower than the particular bandwidth; or (2) the second control frame is received via the lower bandwidth in response to the transmitted first control frame at the particular bandwidth; wherein the transmitter is further configured to transmit data at the lower bandwidth.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the above-recited features of the present disclosure can be understood in detail, a more particular description, briefly summarized above, may be had by reference to aspects, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only certain typical aspects of this disclosure and are therefore not to be considered limiting of its scope, for the description may admit to other equally effective aspects.

FIG. **1** illustrates a diagram of a wireless communications network in accordance with certain aspects of the present disclosure.

FIG. **2** illustrates a block diagram of an example access point and user terminals in accordance with certain aspects of the present disclosure.

FIG. **3** illustrates a block diagram of an example wireless device in accordance with certain aspects of the present disclosure.

FIG. **4** illustrates an example frame structure for wireless communications in accordance with certain aspects of the present disclosure.

FIG. **5** illustrates an example preamble structure in accordance with certain aspects of the present disclosure.

FIG. **6** illustrates an example of a single RTS/CTS frame exchange for bandwidth discovery, in accordance with certain aspects of the present disclosure.

FIG. **7** illustrates example operations to implicitly exchange bandwidth information, from the perspective of a transmitting entity, according to the channels in which the control frames are actually sent, in accordance with certain aspects of the present disclosure.

FIG. **7**A illustrates example means for performing the operations shown in FIG. **7**.

FIG. **8** illustrates example operations to implicitly exchange bandwidth information, from the perspective of a receiving entity, according to the channels in which the control frames are actually sent, in accordance with certain aspects of the present disclosure.

FIG. **8**A illustrates example means for performing the operations shown in FIG. **8**.

FIG. **9** illustrates example operations to explicitly exchange bandwidth information via control frames, from the perspective of a transmitting entity, in accordance with certain aspects of the present disclosure.

FIG. **9**A illustrates example means for performing the operations shown in FIG. **9**.

FIG. **10** illustrates example operations to explicitly exchange bandwidth information via control frames, from the perspective of a receiving entity, in accordance with certain aspects of the present disclosure.

FIG. **10**A illustrates example means for performing the operations shown in FIG. **10**.

FIG. **11** illustrates an example of a double RTS/CTS exchange for bandwidth discovery, in accordance with certain aspects of the present disclosure.

FIG. **12** illustrates indicating bandwidth information via an extension of a legacy RTS frame and a legacy CTS frame, in accordance with certain aspects of the present disclosure.

FIG. **13** illustrates example operations to exchange bandwidth information via control frames using progressively increasing transmission bandwidths, from the perspective of a transmitting entity, in accordance with certain aspects of the present disclosure.

FIG. **13**A illustrates example means for performing the operations shown in FIG. **13**.

FIG. **14** illustrates an example RTS frame structure with explicit bandwidth information, in accordance with certain aspects of the present disclosure.

FIG. **15** illustrates an example CTS frame structure with explicit bandwidth information, in accordance with certain aspects of the present disclosure.

DETAILED DESCRIPTION

Various aspects of the disclosure are described more fully hereinafter with reference to the accompanying drawings. This disclosure may, however, be embodied in many different forms and should not be construed as limited to any specific structure or function presented throughout this disclosure. Rather, these aspects are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art. Based on the teachings herein one skilled in the art should appreciate that the scope of the disclosure is intended to cover any aspect of the disclosure disclosed herein, whether implemented independently of or combined with any other aspect of the disclosure. For example, an apparatus may be implemented or a method may be practiced using any number of the aspects set forth herein. In addition, the scope of the disclosure is intended to cover such an apparatus or method which is practiced using other structure, functionality, or structure and functionality in addition to or other than the various aspects of the disclosure set forth herein. It should be understood that any aspect of the disclosure disclosed herein may be embodied by one or more elements of a claim.

The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any aspect described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects.

Although particular aspects are described herein, many variations and permutations of these aspects fall within the scope of the disclosure. Although some benefits and advantages of the preferred aspects are mentioned, the scope of the disclosure is not intended to be limited to particular benefits, uses, or objectives. Rather, aspects of the disclosure are intended to be broadly applicable to different wireless technologies, system configurations, networks, and transmission protocols, some of which are illustrated by way of example in the figures and in the following description of the preferred aspects. The detailed description and drawings are merely illustrative of the disclosure rather than limiting, the scope of the disclosure being defined by the appended claims and equivalents thereof.

An Example Wireless Communication System

The techniques described herein may be used for various broadband wireless communication systems, including communication systems that are based on an orthogonal multiplexing scheme. Examples of such communication systems include Spatial Division Multiple Access (SDMA), Time Division Multiple Access (TDMA), Orthogonal Frequency Division Multiple Access (OFDMA) systems, Single-Carrier Frequency Division Multiple Access (SC-FDMA) systems, and so forth. An SDMA system may utilize sufficiently different directions to simultaneously transmit data belonging to multiple user terminals. A TDMA system may allow multiple user terminals to share the same frequency channel by dividing the transmission signal into different time slots, each time slot being assigned to different user terminal. An OFDMA system utilizes orthogonal frequency division multiplexing (OFDM), which is a modulation technique that partitions the overall system bandwidth into multiple orthogonal sub-carriers. These sub-carriers may also be called tones, bins, etc. With OFDM, each sub-carrier may be independently modulated with data. An SC-FDMA system may utilize interleaved FDMA (IFDMA) to transmit on sub-carriers that are distributed across the system bandwidth, localized FDMA (LFDMA) to transmit on a block of adjacent sub-carriers, or enhanced FDMA (EFDMA) to transmit on multiple blocks of adjacent sub-carriers. In general, modulation symbols are sent in the frequency domain with OFDM and in the time domain with SC-FDMA.

The teachings herein may be incorporated into (e.g., implemented within or performed by) a variety of wired or wireless apparatuses (e.g., nodes). In some aspects, a wireless node implemented in accordance with the teachings herein may comprise an access point or an access terminal.

An access point ("AP") may comprise, be implemented as, or known as a Node B, a Radio Network Controller ("RNC"), an evolved Node B (eNB), a Base Station Controller ("BSC"), a Base Transceiver Station ("BTS"), a Base Station ("BS"), a Transceiver Function ("TF"), a Radio Router, a Radio Transceiver, a Basic Service Set ("BSS"), an Extended Service Set ("ESS"), a Radio Base Station ("RBS"), or some other terminology.

An access terminal ("AT") may comprise, be implemented as, or known as a subscriber station, a subscriber unit, a mobile station, a remote station, a remote terminal, a user terminal, a user agent, a user device, user equipment, a user station, or some other terminology. In some implementations, an access terminal may comprise a cellular telephone, a cordless telephone, a Session Initiation Protocol ("SIP") phone, a wireless local loop ("WLL") station, a personal digital assistant ("PDA"), a handheld device having wireless connection capability, a Station ("STA"), or some other suitable processing device connected to a wireless modem. Accordingly, one or more aspects taught herein may be incorporated into a phone (e.g., a cellular phone or smart phone), a computer (e.g., a laptop), a portable communication device, a portable computing device (e.g., a personal data assistant), an entertainment device (e.g., a music or video device, or a satellite radio), a global positioning system device, or any other suitable device that is configured to communicate via a wireless or wired medium. In some aspects, the node is a wireless node. Such wireless node may provide, for example, connectivity for or to a network (e.g., a wide area network such as the Internet or a cellular network) via a wired or wireless communication link.

FIG. **1** illustrates a multiple-access multiple-input multiple-output (MIMO) system **100** with access points and user terminals. For simplicity, only one access point **110** is shown in FIG. **1**. An access point is generally a fixed station that communicates with the user terminals and may also be referred to as a base station or some other terminology. A user terminal may be fixed or mobile and may also be referred to as a mobile station, a wireless device, or some other terminology. Access point **110** may communicate with one or more user terminals **120** at any given moment on the downlink and uplink. The downlink (i.e., forward link) is the communication link from the access point to the user terminals, and the uplink (i.e., reverse link) is the communication link from the user terminals to the access point. A user terminal may also communicate peer-to-peer with another user terminal. A system controller **130** couples to and provides coordination and control for the access points.

While portions of the following disclosure will describe user terminals **120** capable of communicating via Spatial Division Multiple Access (SDMA), for certain aspects, the user terminals **120** may also include some user terminals that do not support SDMA. Thus, for such aspects, an AP **110** may be configured to communicate with both SDMA and non-

SDMA user terminals. This approach may conveniently allow older versions of user terminals ("legacy" stations) to remain deployed in an enterprise, extending their useful lifetime, while allowing newer SDMA user terminals to be introduced as deemed appropriate.

The system **100** employs multiple transmit and multiple receive antennas for data transmission on the downlink and uplink. The access point **110** is equipped with N_{ap} antennas and represents the multiple-input (MI) for downlink transmissions and the multiple-output (MO) for uplink transmissions. A set of K selected user terminals **120** collectively represents the multiple-output for downlink transmissions and the multiple-input for uplink transmissions. For pure SDMA, it is desired to have $N_{ap} \geq K \geq 1$ if the data symbol streams for the K user terminals are not multiplexed in code, frequency or time by some means. K may be greater than N_{ap} if the data symbol streams can be multiplexed using TDMA technique, different code channels with CDMA, disjoint sets of subbands with OFDM, and so on. Each selected user terminal transmits user-specific data to and/or receives user-specific data from the access point. In general, each selected user terminal may be equipped with one or multiple antennas (i.e., $N_{ut} \geq 1$). The K selected user terminals can have the same or different number of antennas.

The SDMA system may be a time division duplex (TDD) system or a frequency division duplex (FDD) system. For a TDD system, the downlink and uplink share the same frequency band. For an FDD system, the downlink and uplink use different frequency bands. MIMO system **100** may also utilize a single carrier or multiple carriers for transmission. Each user terminal may be equipped with a single antenna (e.g., in order to keep costs down) or multiple antennas (e.g., where the additional cost can be supported). The system **100** may also be a TDMA system if the user terminals **120** share the same frequency channel by dividing transmission/reception into different time slots, each time slot being assigned to different user terminal **120**.

FIG. **2** illustrates a block diagram of access point **110** and two user terminals **120***m* and **120***x* in MIMO system **100**. The access point **110** is equipped with N_t antennas **224***a* through **224***t*. User terminal **120***m* is equipped with $N_{ut,m}$ antennas **252***ma* through **252***mu*, and user terminal **120***x* is equipped with N_{at} antennas **252***xa* through **252***xu*. The access point **110** is a transmitting entity for the downlink and a receiving entity for the uplink. Each user terminal **120** is a transmitting entity for the uplink and a receiving entity for the downlink. As used herein, a "transmitting entity" is an independently operated apparatus or device capable of transmitting data via a wireless channel, and a "receiving entity" is an independently operated apparatus or device capable of receiving data via a wireless channel. In the following description, the subscript "dn" denotes the downlink, the subscript "up" denotes the uplink, N_{up}, user terminals are selected for simultaneous transmission on the uplink, N_{dn} user terminals are selected for simultaneous transmission on the downlink, N_{up}, may or may not be equal to N_{dn}, and N_{up}, and N_{dn} may be static values or can change for each scheduling interval. The beam-steering or some other spatial processing technique may be used at the access point and user terminal.

On the uplink, at each user terminal **120** selected for uplink transmission, a TX data processor **288** receives traffic data from a data source **286** and control data from a controller **280**. TX data processor **288** processes (e.g., encodes, interleaves, and modulates) the traffic data for the user terminal based on the coding and modulation schemes associated with the rate selected for the user terminal and provides a data symbol stream. A TX spatial processor **290** performs spatial processing on the data symbol stream and provides $N_{ut,m}$ transmit symbol streams for the $N_{ut,m}$ antennas. Each transmitter unit (TMTR) **254** receives and processes (e.g., converts to analog, amplifies, filters, and frequency upconverts) a respective transmit symbol stream to generate an uplink signal. $N_{ut,m}$ transmitter units **254** provide $N_{ut,m}$ uplink signals for transmission from $N_{ut,m}$ antennas **252** to the access point.

N_{up}, user terminals may be scheduled for simultaneous transmission on the uplink. Each of these user terminals performs spatial processing on its data symbol stream and transmits its set of transmit symbol streams on the uplink to the access point.

At access point **110**, N_{ap} antennas **224***a* through **224***ap* receive the uplink signals from all N_{up} user terminals transmitting on the uplink. Each antenna **224** provides a received signal to a respective receiver unit (RCVR) **222**. Each receiver unit **222** performs processing complementary to that performed by transmitter unit **254** and provides a received symbol stream. An RX spatial processor **240** performs receiver spatial processing on the N_{ap} received symbol streams from N_{ap} receiver units **222** and provides N_{up} recovered uplink data symbol streams. The receiver spatial processing is performed in accordance with the channel correlation matrix inversion (CCMI), minimum mean square error (MMSE), soft interference cancellation (SIC), or some other technique. Each recovered uplink data symbol stream is an estimate of a data symbol stream transmitted by a respective user terminal. An RX data processor **242** processes (e.g., demodulates, deinterleaves, and decodes) each recovered uplink data symbol stream in accordance with the rate used for that stream to obtain decoded data. The decoded data for each user terminal may be provided to a data sink **244** for storage and/or a controller **230** for further processing.

On the downlink, at access point **110**, a TX data processor **210** receives traffic data from a data source **208** for N_{dn} user terminals scheduled for downlink transmission, control data from a controller **230**, and possibly other data from a scheduler **234**. The various types of data may be sent on different transport channels. TX data processor **210** processes (e.g., encodes, interleaves, and modulates) the traffic data for each user terminal based on the rate selected for that user terminal TX data processor **210** provides N_{dn} downlink data symbol streams for the N_{dn} user terminals. A TX spatial processor **220** performs spatial processing (such as a precoding or beamforming, as described in the present disclosure) on the N_{dn} downlink data symbol streams, and provides N_{ap} transmit symbol streams for the N_{ap} antennas. Each transmitter unit **222** receives and processes a respective transmit symbol stream to generate a downlink signal. N_{ap} transmitter units **222** providing N_{ap} downlink signals for transmission from N_{ap} antennas **224** to the user terminals.

At each user terminal **120**, $N_{ut,m}$ antennas **252** receive the N_{ap} downlink signals from access point **110**. Each receiver unit **254** processes a received signal from an associated antenna **252** and provides a received symbol stream. An RX spatial processor **260** performs receiver spatial processing on $N_{ut,m}$ received symbol streams from $N_{ut,m}$ receiver units **254** and provides a recovered downlink data symbol stream for the user terminal. The receiver spatial processing is performed in accordance with the CCMI, MMSE or some other technique. An RX data processor **270** processes (e.g., demodulates, deinterleaves and decodes) the recovered downlink data symbol stream to obtain decoded data for the user terminal.

At each user terminal **120**, a channel estimator **278** estimates the downlink channel response and provides downlink channel estimates, which may include channel gain estimates, SNR estimates, noise variance and so on. Similarly, a

channel estimator **228** estimates the uplink channel response and provides uplink channel estimates. Controller **280** for each user terminal typically derives the spatial filter matrix for the user terminal based on the downlink channel response matrix $H_{dn,m}$ for that user terminal. Controller **230** derives the spatial filter matrix for the access point based on the effective uplink channel response matrix $H_{up,eff}$. Controller **280** for each user terminal may send feedback information (e.g., the downlink and/or uplink eigenvectors, eigenvalues, SNR estimates, and so on) to the access point. Controllers **230** and **280** also control the operation of various processing units at access point **110** and user terminal **120**, respectively.

FIG. **3** illustrates various components that may be utilized in a wireless device **302** that may be employed within the MIMO system **100**. The wireless device **302** is an example of a device that may be configured to implement the various methods described herein. The wireless device **302** may be an access point **110** or a user terminal **120**.

The wireless device **302** may include a processor **304** which controls operation of the wireless device **302**. The processor **304** may also be referred to as a central processing unit (CPU). Memory **306**, which may include both read-only memory (ROM) and random access memory (RAM), provides instructions and data to the processor **304**. A portion of the memory **306** may also include non-volatile random access memory (NVRAM). The processor **304** typically performs logical and arithmetic operations based on program instructions stored within the memory **306**. The instructions in the memory **306** may be executable to implement the methods described herein.

The wireless device **302** may also include a housing **308** that may include a transmitter **310** and a receiver **312** to allow transmission and reception of data between the wireless device **302** and a remote location. The transmitter **310** and receiver **312** may be combined into a transceiver **314**. A single or a plurality of transmit antennas **316** may be attached to the housing **308** and electrically coupled to the transceiver **314**. The wireless device **302** may also include (not shown) multiple transmitters, multiple receivers, and multiple transceivers.

The wireless device **302** may also include a signal detector **318** that may be used in an effort to detect and quantify the level of signals received by the transceiver **314**. The signal detector **318** may detect such signals as total energy, energy per subcarrier per symbol, power spectral density and other signals. The wireless device **302** may also include a digital signal processor (DSP) **320** for use in processing signals.

The various components of the wireless device **302** may be coupled together by a bus system **322**, which may include a power bus, a control signal bus, and a status signal bus in addition to a data bus.

An Example Frame Structure

In order to communicate, the access point (AP) **110** and the user terminals **120** in a wireless network (e.g., system **100** illustrated in FIG. **1**) may exchange messages according to certain frame structures. FIG. **4** illustrates an example frame structure **400** for wireless communications in accordance with certain aspects of the present disclosure. A short control frame, such as a Request to Send (RTS) or a Clear to Send (CTS) frame may comprise this frame structure. The frame structure **400** may comprise a preamble **500**, a Media Access Control (MAC) header **402**, a frame body **404**, and a frame check sequence (FCS) **406**.

FIG. **5** illustrates an example structure of a preamble **500** in accordance with certain aspects of the present disclosure. The preamble **500** may comprise an omni-legacy portion **502** (i.e., the non-beamformed portion) and a precoded 802.11ac VHT (Very High Throughput) portion **504**. The legacy portion **502** may comprise a Legacy Short Training Field (L-STF) **506**, a Legacy Long Training Field **508**, a Legacy Signal (L-SIG) field **510**, and two OFDM symbols in two VHT Signal A (VHT-SIG-A) fields **512**, **514**. For certain aspects, the legacy portion **502** may also comprise a group identifier (ID) field **516** to convey to all supported STAs that a particular set of STAs will be receiving spatial streams of a MU-MIMO transmission.

The precoded 802.11ac VHT portion **504** may comprise a VHT Short Training Field (VHT-STF) **518**, a VHT Long Training Field 1 (VHT-LTF1) **520**, VHT Long Training Fields (VHT-LTFs) **522**, a VHT Signal B (VHT-SIG-B) field **524**, and a data portion **526**. The VHT-SIG-B field **524** may comprise one OFDM symbol and may be transmitted precoded/beamformed.

Example RTS and CTS for Multichannel Operations

IEEE 802.11ac is an amendment to the IEEE 802.11 standard that enables higher throughput in 802.11 networks. The higher throughput is realized through several measures, such as the use of MU-MIMO (multiuser multiple input multiple output) and 80 MHz or 160 MHz channel bandwidth. 802.11ac is also referred to as Very High Throughput (VHT).

In 802.11ac networks, the basic channel unit is about 20 MHz wide. Each PPDU (physical layer conversion protocol (PLCP) protocol data unit) can span 20, 40, 80, or 160 MHz (i.e., one, two, four, or eight 20 MHz channels). Each transmitting entity is assigned a primary channel from the plurality of channels used for transmitting data. The transmission procedure consists of performing real and virtual carrier sensing on the primary channel and real carrier sensing on the other channels to determine the plurality of channels that can be used.

However, due to the wider PPDU bandwidths and higher likelihood of hidden nodes, there is a need for determining the free (i.e., available) channels around the receiver before determining the bandwidth of a PPDU. The resulting PPDU will span the lesser of the "free" bandwidth around the transmitting entity and the free bandwidth around the receiving entity.

Accordingly what is needed are techniques and apparatus for efficiently determining the free bandwidth around the receiver. Moreover, such bandwidth determinations would preferably allow for setting the Network Allocation Vector (NAV) counter for other STAs, reserving the wireless medium and protecting the transmission from hidden nodes.

FIG. **6** illustrates an example of a single RTS/CTS frame exchange **600** for bandwidth discovery, in accordance with certain aspects of the present disclosure. For an 80 MHz transmission according to the IEEE 802.11ac amendment, short control frames, such as Request to Send (RTS) frames **602**, may be transmitted on four 20 MHz channels (CH**1**-CH**4**) from a transmitting entity (e.g., an AP **110**) for sending data. In duplicate mode, the RTS frame **602** to be transmitted on the primary channel (e.g., CH**1**) may be copied and transmitted via the other channels (e.g., CH**2**-CH**4**) simultaneously with the RTS frame sent via the primary channel as shown.

A receiving entity (e.g., a user terminal **120**) may determine the channels over which the RTS frames were sent and the channels determined to be available around the receiving entity. The receiving entity may then transmit short control

frames, such as Clear to Send (CTS) frames **604**, in response to the received RTS frames **602** on the available channels (e.g., CH**1**-CH**2**).

The transmitting entity may determine the channels over which the CTS frames **604** were sent. The transmitting entity may subsequently transmit data **606** over the available channels (the channels on which the CTS frames **604** were sent). As illustrated in FIG. **6**, the bandwidth to be used for transmitting data may be 40 MHz (i.e., two 20 MHz channels) according to the IEEE 802.11ac amendment.

As a general overview, aspects of the present disclosure primarily address how to exchange available bandwidth (BW) information between a transmitter and a receiver. This exchange of bandwidth information may be performed implicitly—by determining the channels in which the RTS/CTS frames are actually sent—or explicitly. Explicit bandwidth information exchange may be accomplished by hiding information in a legacy (already existing according to the IEEE 802.11a/b/g amendments) frame format (referred to herein as a legacy RTS frame) or by defining a new frame format which carries a bandwidth information field (referred to herein as a VHT RTS frame).

Certain aspects of the present disclosure also address how to send the RTS/CTS frames so as to provide protection for the transmitter and the receiver. As described herein, protection generally refers to the RTS/CTS mechanism reserving the wireless medium for a time interval long enough to transmit a data frame and to receive the associated acknowledgement (ACK) frame.

Certain aspects may perform an RTS/CTS exchange using a legacy preamble and a legacy frame format. The RTS/CTS frames may carry the NAV information to cover the data transmission. This may most likely provide protection against legacy and VHT STAs. Such aspects may employ the implicit or the explicit bandwidth signaling mechanism.

Certain other aspects may perform an RTS/CTS exchange using a legacy or a VHT preamble and a VHT frame format including BW information. The RTS/CTS frames may carry the NAV information to cover the data transmission. This may most likely provide protection against legacy and VHT STAs. However, legacy STAs may be penalized due to the fact that the VHT RTS frame may not trigger the same behavior as a legacy RTS frame.

Certain other aspects may perform an RTS/CTS exchange using a legacy or a VHT preamble and a VHT frame format, which includes explicit BW information. RTS/CTS NAV may be set to cover only the RTS/CTS exchange. This initial RTS/CTS exchange may be followed with a subsequent RTS/CTS exchange using a legacy preamble and a legacy frame format. These legacy RTS/CTS frames may carry the NAV information to cover the data transmission. This may most likely provide protection against legacy and VHT STAs.

Certain other aspects may perform an initial RTS/CTS exchange using a legacy preamble and a legacy frame format followed by a subsequent RTS/CTS frame exchange with legacy or VHT preamble and a VHT frame format with explicit BW information.

FIG. **7** illustrates example operations **700** to implicitly exchange bandwidth information according to the channels in which the control frames are actually sent. The operations **700** may be performed by a transmitting entity, such as an AP **110**. The operations **700** may begin, at **702**, by transmitting, to an apparatus (e.g., the receiving entity), a first control frame on each of one or more channels desired for transmitting data to the apparatus. At **704**, a second control frame may be received on each of at least a portion of the channels, wherein the channels in the portion of the channels are available at the apparatus. At **706**, the transmitting entity may transmit the data using the at least the portion of the channels.

FIG. **8** illustrates example operations **800** to implicitly exchange bandwidth information according to the channels in which the control frames are actually sent. The operations **800** may be performed by a receiving entity, such as a user terminal **120**. The operations **800** may begin, at **802**, by receiving, at an apparatus (e.g., the receiving entity), a first control frame on each of one or more channels desired for sending data to the apparatus. At **804**, in response to receiving the first control frame, the receiving entity may transmit a second control frame on each of at least a portion of the channels, wherein the channels in the portion of the channels are available at the apparatus. At **806**, the receiving entity may receive the data sent using the at least the portion of the channels.

Method 1

A first method jointly addresses two aspects of the present disclosure: (1) the channels in which the RTS/CTS frames are sent implicitly represent the BW information and (2) define the protection level. This method may comprise utilizing the RTS and CTS frames sent using duplicate or copy mode. In other words, the RTS PPDU to be sent over the primary (20 MHz) channel is copied in all or some of the other 20 MHz channels that the transmitter intends to use for the transmission.

The RTS frame may be sent by using a preamble and frame format according to the IEEE 802.11a amendment (also referred to as a legacy RTS frame). Note that such an RTS frame does not carry any explicit indication of transmitted bandwidth. Rather, this method relies on the ability of the receiver to detect on which channels the (copies of the) RTS frames are sent.

The steps in this method may comprise:

Step 1: The transmitting entity (e.g., a transmitting station denoted "TxSTA") may send one or more RTS frames using duplicate mode over channels that are sensed to be free at the TxSTA. These free channels may represent channels desired for transmitting data (i.e., desired channels). Definition of free channels may include having the carrier sensing indicate that the wireless medium was idle for PIFS (point coordination function (PCF) interframe space) time before the transmission start. For example, the RTS frames **602** may be sent on CH**1**-CH**4** as illustrated in FIG. **6**.

Step 2: The receiving entity (e.g., a receiving station denoted "RxSTA") may receive the RTS frames and determine the channels over which the RTS frames were sent using any of various suitable techniques, such as multi-channel Short Training Field (STF) detection. Note that this detection does not use explicit signaling, but relies on signal detection capabilities at the physical (PHY) layer. Let "CH_RTS" denote the channels that are determined at the receiver to be the channels over which the RTS frames were received.

Step 3: RxSTA may send one or more CTS frames to TxSTA on a subset of CH_RTS that is determined to be free around RxSTA. For example, the CTS frames **604** may be sent on CH**1**-CH**2** as illustrated in FIG. **6**.

Step 4: TxSTA may receive the CTS frames sent by RxSTA and may determine the channels over which the CTS frames were sent. The TxSTA may then send data over the channels (e.g., CH**1**-CH**2** as shown in FIG. **6**) on which the CTS frames were sent. Note that the determination of the channels on which the CTS frames were received does not use an explicit signaling, but relies on signal detection capabilities at the PHY layer.

FIG. **9** illustrates example operations **900** to explicitly exchange bandwidth information via control frames. The operations **900** may be performed by a transmitting entity, such as an AP **110**. The operations **900** may begin, at **902**, by transmitting, to an apparatus (e.g., a receiving entity), a first control frame indicating a desired bandwidth for transmitting data to the apparatus. At **904**, the transmitting entity may receive a second control frame indicating an available bandwidth of the apparatus. The transmitting entity may transmit the data, at **906**, based on the lesser of the available bandwidth and the desired bandwidth.

FIG. **10** illustrates example operations **1000** to explicitly exchange bandwidth information via control frames. The operations may be performed by a receiving entity, such as a user terminal **120**. The operations **1000** may begin, at **1002**, by receiving, at an apparatus (e.g., the receiving entity), a first control frame indicating a desired bandwidth for sending data to the apparatus. At **1004**, in response to receiving the first control frame, the apparatus may transmit a second control frame indicating an available bandwidth to the apparatus. At **1006**, the apparatus may receive the data sent using the lesser of the available bandwidth and the desired bandwidth.

Method 2

A second method addresses only the BW information exchange. Method 2 differs from Method 1 in that transmitted bandwidth information is included in the RTS/CTS frames that are sent using either a legacy or a VHT frame packet preamble. The main issue to be solved in method 2 is ensuring that the RTS/CTS frames that include the bandwidth information still function as valid RTS/CTS frames for legacy devices. Several techniques for accomplishing this are described below for Method 2.

Using the Duration Field of the RTS/CTS Frames (Version 1)

The idea with this first technique is to use bits, such as two or more of the least significant bits (LSBs), of the Duration field **408** of the MAC header **402** as a bandwidth indicator. In this manner, the bandwidth indication may be "hidden" in a legacy RTS or CTS frame. Two bits are sufficient to indicate the use of 20, 40, 80, 160 MHz bandwidths. Note that the Duration field **408** indicates time in microseconds (μs). For certain aspects, at least one most significant bit (MSB) of the Duration field **408** may indicate that the Duration field includes the bandwidth information.

Step 1: The transmitting entity may compute the transmission time T based on data to be transmitted, define T**1**=4*ceil (T/4), define T_RTS=T**1**+(LSBs to indicate BW), and set the Duration field of the transmitted RTS frame to T_RTS.

Step 2: A VHT-capable STA which is the intended recipient of the RTS frame may determine the desired reservation end time based on T**1**, which is obtained from T_RTS (in the Duration field **408** of the RTS) by first setting the LSBs to zero. A legacy STA—or a VHT STA which is not the intended recipient of the RTS frame—may simply set the reserved time to T_RTS.

Step 3: A VHT-capable RxSTA may compute the Duration field for the CTS (defined as T_CTS) as follows: T_CTS=T**1**+ (LSBs to indicate the available BW at the RxSTA).

Step 4: TxSTA may receive a CTS frame from RxSTA and use the LSBs of the Duration field to determine the bandwidth available to be used.

Using the Duration Field of the RTS/CTS (Version 2)

This second technique may use the same scheme as Version 1, with certain modifications described below. Note that a CTS frame might slightly extend the NAV that is set by the RTS. To avoid this problem, the Duration field may be "pre-"increased by 4 μs to build in sufficient margin.

Step 1: The transmitting entity may compute the transmission time T based on data to be transmitted, define T**1**=4*(1+ ceil(T/4)), define T_RTS=T**1**+(LSBs to indicate BW), and set the Duration field **408** of the RTS to be transmitted to T_RTS.

Step 2: Same as step 2 of Version 1.

Step 3: A VHT-capable RxSTA may compute the Duration field for the CTS frame (defined as T_CTS) according to T_CTS=T**1**−(LSBs to indicate the available BW at the RxSTA).

Step 4: Same as step 4 of Version 1.

Using the L-SIG Field

For certain aspects, the RTS/CTS frames may comprise a legacy preamble. This legacy preamble may have a legacy signal (L-SIG) field **510**, and a bit of the L-SIG field may be used to indicate whether the RTS/CTS frame includes the bandwidth information. For certain aspects, at least one of an in-phase (I) component or a quadrature (Q) component of the L-SIG field may indicate whether the RTS or CTS frame includes the bandwidth information.

Use of the L-SIG field may be combined with other techniques disclosed in Method 2. For example, two LSBs of the Duration field **408** may indicate the bandwidth information in a legacy RTS/CTS frame, while one bit of the L-SIG field may indicate that the Duration field includes the bandwidth information.

Using the Service field bits

For certain aspects, Service field bits may be used as a bandwidth indication. Used for scrambler initialization, the Service field may comprise the first portion (e.g., the first 16 bits) of the Data field (the data portion **526**). As one option, any two of the 9 reserved Service bits (according to the IEEE 802.11a amendment) may be used to indicate the bandwidth. For certain aspects, one additional bit for parity may also be included.

As a second option, the scrambler initialization seed may be used to indicate the bandwidth. For certain aspects utilizing this second option, scrambler seeds may be defined for each bandwidth. For example, four total scrambler seeds may be defined for 20, 40, 80, and 160 MHz. For other aspects, the TxSTA of each Basic Service Set (BSS) may define the bits to be used in the scrambler for each bandwidth.

A legacy receiver STA would not be affected. A VHT-capable STA, receiving the RTS, may check the transmitter address of the RTS. If the RTS is sent by a VHT STA, the receiver STA may use the information in the scrambler field to determine the BW. If the RTS is sent by a legacy STA, the receiver STA may deem that no BW information was sent.

Using Frame Control Bits

For certain aspects, bits in the Frame Control field **410** of the MAC header **402** of an RTS/CTS frame may be used as a bandwidth indication. Currently there are 7 "useless" bits, all set to 0. For certain aspects, one of the Frame Control bits may be used to indicate that the RTS/CTS frame is a new type of RTS/CTS frame with bandwidth information, and two or more other bits may be used to indicate the bandwidth information.

Using NAV Bits

For certain aspects, two or more bits (e.g., 2 LSBs) of the NAV may be used as a bandwidth indication. A VHT STA receiving an RTS frame may be informed that the RTS frame was sent by a VHT STA. Such notice may be provided using the sender's address, which may indicate the type of STA (i.e., legacy versus VHT STA).

In addition to the techniques described above, other techniques may be employed for exchanging bandwidth informa-

tion included in the RTS/CTS frames. For certain aspects, bits in a physical layer (PHY) legacy preamble may be reused to indicate the bandwidth information. However, this may have an adverse affect on legacy STAs.

Method 3

A third method involves using an updated 802.11ac preamble. This method jointly addresses the BW information exchange and the frame exchange for medium reservation.

Step 1: TxSTA may send an RTS frame with a VHT (802.11ac) preamble using duplicate mode for the data portion of the RTS PPDU. In order to signal the duplicate mode of operation, one of the currently reserved bits of the VHT-SIG-A field **512** may be re-labeled to denote duplicate mode. This duplicate mode bit may be set to "1," and the channel bandwidth bits may denote the bandwidth over which the RTS frame is sent.

Step 2: RxSTA may receive the RTS frame and determine the channels over which the RTS was sent by using a combination of the duplicate mode bit and the channel bandwidth indicator in the RTS frame. CH_RTS may denote the channels that are determined at the receiver to be the channels over which the RTS was received.

Step 3: RxSTA may send a CTS frame to TxSTA on a subset of CH_RTS that is determined to be free around RxSTA. The VHT-SIG-A duplicate mode bit may be set if more than one 20 MHz channel is used, and the channel bandwidth bits may indicate the bandwidth over which the CTS is sent.

Step 4: TxSTA may receive the CTS frame sent by RxSTA. TxSTA may determine the channels over which the CTS was sent (using information from VHT-SIG-A) and send data over the channels on which the CTS was sent.

Method 4

A fourth method addresses the BW information exchange only. In Method 4, a new format of RTS frame (referred to as VHT-RTS) may be defined. Note that this refers to the frame format and not to the PHY preamble. The preamble may be a legacy preamble or a VHT preamble. When sent with a legacy preamble, legacy STAs may most likely be able to decode the signal, but the VHT-RTS frame will not look like an RTS frame to them. Legacy STAs will simply set the Network Allocation Vector (NAV) according to the Duration field **408**. The Duration field in the VHT-RTS frame may indicate a NAV covering enough time for reception of the CTS frame, a short interframe space (SIFS), and subsequent transmission of the data.

The VHT-RTS frame format may contain a new field with an explicit indication of the BW. Similarly, a new frame format for CTS (referred to as VHT-CTS) may be defined, including a field which indicates the BW. The new RTS/CTS frames may be a new control frame or may use a control wrapper.

Method 5

In this fifth method, the RTS/CTS frame may comprise a High Throughput Control (HTC) field having a certain number of bits. For certain aspects, two or more bits of the HTC field may indicate the desired bandwidth.

Method 6

A sixth method addresses the frame exchange for protection. In Method 6, VHT RTS/CTS frames containing explicit BW information may be exchanged in order to discover the available BW. The NAV set by the VHT RTS/CTS may cover only the RTS/CTS exchange, not the data exchange. FIG. **11** illustrates an example of a double RTS/CTS exchange **1100** for bandwidth discovery, in accordance with Method 6.

First, TxSTA may send one or more VHT-RTS frames **1102** with legacy duplicate or VHT preambles on known free channels (e.g., CH**1**-CH**4** as illustrated in FIG. **11**). Second, RxSTA may send one or more VHT-CTS frames **1104** with legacy duplicate or VHT preambles on known free channels among the channels indicated by the VHT-RTS frames **1102** (e.g., CH**1**-CH**2** as illustrated in FIG. **11**).

Following the previous exchange, legacy RTS/CTS frames may be exchanged. In other words, TxSTA may send one or more legacy RTS (L-RTS) frames **1106** with legacy preambles in duplicate mode on the channels indicated by the VHT-CTS frames **1104** using copy mode. Then, RxSTA may send legacy CTS (L-CTS) frames **1108** with legacy preambles duplicated on the free channels indicated previously by the VHT-CTS frames **1104**. After receiving the legacy CTS frames **1108**, TxSTA may send data **1110** on the channels indicated by the VHT-CTS frames **1104**.

As mentioned above, the NAV set by the VHT-RTS/CTS frames may cover only the RTS/CTS exchange, not the data exchange. For example, the Duration field **408** in the VHT-RTS frame **1102** may indicate a NAV covering enough time for reception of the VHT-CTS frame **1104**, a short interframe space (SIFS), and subsequent transmission of a legacy RTS frame **1106** for certain aspects. For other aspects, the Duration field **408** in the VHT-RTS frame **1102** may indicate a NAV covering enough time for reception of the VHT-CTS frame **1104**, a first SIFS, subsequent transmission of a legacy RTS frame **1106**, a second SIFS, and reception of a legacy CTS frame **1108**.

In contrast, the NAV set by the legacy RTS/CTS mechanism may cover the data exchange. For example, the Duration field **408** in the L-RTS frame **1106** may indicate a NAV covering enough time for reception of the L-CTS frame **1108**, a short interframe space (SIFS), and subsequent transmission of the data **1110**. In this manner, the NAV set by the legacy RTS and legacy CTS frames protects the transmission of the data.

Method 7

Similar to Method 6 described above, Method 7 also involves a double RTS/CTS exchange for bandwidth discovery using explicit bandwidth information. However, Method 7 entails exchanging legacy RTS/CTS frames before exchanging VHT-RTS/CTS frames.

More specifically, TxSTA may send a legacy RTS frame on the primary channel (or on all the channels in copy mode). RxSTA may receive the legacy RTS frame and send a legacy CTS frame on all the channels that are idle. Since no explicit information is carried by these frames, the BW determination may not be available (unless performed implicitly as described above for Method 1). The previous exchange may be followed by TxSTA sending a VHT-RTS frame with a VHT or a legacy preamble using copy mode on free channels. The VHT-RTS frame may indicate free channels at the transmitting entity side. RxSTA may send a VHT-CTS frame with a legacy or a VHT preamble using copy mode on the available channels. The VHT-CTS frame may indicate the free channels at the receiving entity side. Subsequently, TxSTA may send data on channels indicated by the VHT-CTS frame.

Method 8

Method 8 may involve indicating bandwidth information explicitly via an extension of the legacy RTS/CTS frames. As

illustrated in FIG. **12**, a VHT-RTS frame **1200** (or a VHT-CTS frame **1250**) may comprise a legacy RTS frame (or a legacy CTS frame) and one extra piggy-backed symbol called the VHT Augmented Field (VAF) **1210** (or **1260**). The duration indicated by the L-SIG field **1202** (or **1252**) may only cover the RTS Media Access Control (MAC) protocol data unit (MPDU) **1204** (or the CTS MPDU **1254**) and not the VAF.

Method 8 may allow legacy nodes to decode the RTS/CTS messages and set NAV. However, VHT STAs may prepare to decode one extra symbol if the L-SIG length field indicates the length of an RTS frame (20 bytes) or of a CTS frame (14 bytes). VHT STAs may most likely be capable of responding to an RTS in less than the SIFS (short interframe space), so only 12 μs budget may be allowed for the VAF **1210**, **1260**.

The VAF may be transmitted with various data rate options. For certain aspects, the VAF may be sent at the lowest rate. For other aspects, the VAF may be sent at the same data rate as the preceding MPDU, which may provide a decoding advantage. For certain aspects, the VAF may be sent in "copy" mode like the RTS/CTS MPDU.

Only 24 bits of the VAF **1210**, **1260** may be valid. The VAF may be designed to exactly fit one symbol at 6 Mb/s. Other bits may be set to padding or to a fixed pattern. For certain aspects, the VAF **1210**, **1260** may contain at least an 8-bit Cyclic Redundancy Check (CRC) and 6 tail bits. An 8-bit CRC may enable robust detection. With a 24-bit VAF, 10 information bits may be available for indicating the bandwidth.

For certain aspects, even if the VAF of a VHT-RTS frame **1200** is not detected, the destination VHT-capable STA may send a VHT-CTS frame **1250** on the primary channel, for example.

Method 9

A ninth method jointly addresses the BW information exchange and the frame exchange for protection. Method 9 may involve the following steps:

Step 1: TxSTA may send a VHT-RTS frame using a VHT preamble without duplicate mode on only the primary channel (i.e., with 20 MHz bandwidth) and receive a VHT-CTS frame.

Step 2: TxSTA may send VHT-RTS frames with progressively increasing bandwidth (e.g., 40 MHz and then 80 MHz, using two and then four channels, respectively).

Step 3: If a VHT-CTS frame is received in response to Step 2 above indicating a lower bandwidth than the VHT-RTS frame, then TxSTA may stop sending VHT-RTS and send data according to the bandwidth indicated by the received VHT-CTS frame. If a VHT-CTS frame is not received in response to Step 2, then TxSTA may use PIFS continuation to send data on the known available channels. For example, if a VHT-CTS frame is not received in response to a VHT-RTS frame for higher bandwidths in Step 2, then TxSTA may transmit data at the highest bandwidth of the VHT-CTS frames received thus far.

FIG. **13** illustrates example operations **1300** to exchange bandwidth information via control frames using progressively increasing transmission bandwidths in accordance with Method 9. The operations **1300** may be performed by a transmitting entity (e.g., an access point **110**). The operations **1300** may begin, at **1302**, by transmitting, to an apparatus (e.g., a receiving entity, such as a user terminal **120**), a first control frame via a first bandwidth. At **1304**, the transmitting entity may receive a second control frame via the first bandwidth. At **1306**, the transmitting entity may repeat transmission, to the apparatus, of the first control frame via progressively increasing transmission bandwidths. The transmission may be repeated until either: (1) the second control frame is not received in response to the transmitted first control frame at a particular bandwidth, but was received at a bandwidth lower than the particular bandwidth; or (2) the second control frame is received via the lower bandwidth in response to the transmitted first control frame at the particular bandwidth. At **1308**, the transmitting entity may transmit data, to the apparatus, at the lower bandwidth.

For certain aspects that send explicit BW information, the BW information may be transmitted in the NAV or the Frame Control fields **410** of the RTS/CTS frames. The receiving entity may check that the transmit address of the RTS frame corresponds to a multichannel-capable STA or other entity (i.e., a VHT device supporting 802.11ac, 802.11af, or later amendments) before determining the explicit BW information. For certain aspects, the check that an RTS/CTS frame has been sent by a multichannel-capable device may be based on a table lookup. For other aspects, the check that an RTS/CTS frame has been sent by a multichannel-capable entity may be based on the address belonging to a set of—or being in a range of—addresses that are allocated by a standardization body, for example.

As illustrated in FIG. **14**, explicit BW information may be provided in an RTS frame **1400**. According to certain aspects, the RTS frame **1400** may be based on the legacy RTS, but with a few differences. A field **1402** comprising one extra byte (1 octet) may be included in the RTS frame and located before the FCS field **1404**. The extra byte field **1402** may comprise, for example, a 2-bit BW indication (denoted as the "BW Info" field **1406**. Other bits of this field **1402** may be reserved (denoted as "RSVD") for future optional features. According to certain aspects, this frame **1400** may be a new control frame defined by using the subtype extension as in the IEEE 802.11ad amendment. As an example, the control frame may be defined using type Control (01) and subtype Control frame extension (0110) according to 802.11ad, extended subtype 1011. As another example, the control frame may be defined using type Extension (11) and subtype VHT-RTS (0001).

As illustrated in FIG. **15**, explicit BW information may be provided in a CTS frame **1500**. According to certain aspects, the CTS frame **1500** may based on the legacy CTS, but with a few differences. A field **1502** comprising one extra byte (8 bits) may be included in the CTS frame and located before the FCS field **1504**. The extra byte field **1502** may comprise, for example, a 2-bit BW indication (denoted as the "BW Info" field **1506**. Other bits of this field **1502** may be reserved (denoted as "RSVD") for future optional features. According to certain aspects, this frame **1500** may be a new control frame defined by using the subtype extension as in the IEEE 802.11ad amendment. As an example, the control frame may be defined using type Control (01) and subtype Control frame extension (0110) according to 802.11ad, extended subtype 1100. As another example, the control frame may be defined using type Extension (11) and subtype VHT-CTS (0010).

The methods and apparatus described above provide various options for signaling the bandwidth to be used for wireless communications using an RTS/CTS exchange, providing for bandwidths of at least 20 MHz, 40 MHz, 80 MHz, 160 MHz, or higher. In addition to this bandwidth information exchange, aspects of the present disclosure may also allow for NAV protection in multiple channels.

The various operations of methods described above may be performed by any suitable means capable of performing the corresponding functions. The means may include various hardware and/or software component(s) and/or module(s), including, but not limited to a circuit, an application specific

integrated circuit (ASIC), or processor. Generally, where there are operations illustrated in figures, those operations may have corresponding counterpart means-plus-function components with similar numbering. For example, operations **700** illustrated in FIG. **7** correspond to means **700**A illustrated in FIG. **7**A.

For example, means for transmitting the first control frame and/or the data may comprise a transmitter, such as the transmitter unit **222** of the access point **110** illustrated in FIG. **2**, the transmitter unit **254** of the user terminal **120** depicted in FIG. **2**, or the transmitter **310** of the wireless device **302** shown in FIG. **3**. Means for receiving may comprise a receiver, such as the receiver unit **222** of the access point **110** illustrated in FIG. **2**, the receiver unit **254** of the user terminal **120** depicted in FIG. **2**, or the receiver **312** of the wireless device **302** shown in FIG. **3**. Means for checking an address of a received RTS frame and/or means for determining desired channels may comprise a processing system, which may include one or more processors, such as the RX data processor **270** and/or the controller **280** of the user terminal **120** or the RX data processor **242** and/or the controller **230** of the access point **110** illustrated in FIG. **2**.

As used herein, the term "determining" encompasses a wide variety of actions. For example, "determining" may include calculating, computing, processing, deriving, investigating, looking up (e.g., looking up in a table, a database or another data structure), ascertaining and the like. Also, "determining" may include receiving (e.g., receiving information), accessing (e.g., accessing data in a memory), and the like. Also, "determining" may include resolving, selecting, choosing, establishing, and the like.

As used herein, a phrase referring to "at least one of" a list of items refers to any combination of those items, including single members. As an example, "at least one of: a, b, or c" is intended to cover: a, b, c, a-b, a-c, b-c, and a-b-c.

The various illustrative logical blocks, modules and circuits described in connection with the present disclosure may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device (PLD), discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any commercially available processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

The steps of a method or algorithm described in connection with the present disclosure may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in any form of storage medium that is known in the art. Some examples of storage media that may be used include random access memory (RAM), read only memory (ROM), flash memory, EPROM memory, EEPROM memory, registers, a hard disk, a removable disk, a CD-ROM, and so forth. A software module may comprise a single instruction, or many instructions, and may be distributed over several different code segments, among different programs, and across multiple storage media. A storage medium may be coupled to a processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor.

The methods disclosed herein comprise one or more steps or actions for achieving the described method. The method steps and/or actions may be interchanged with one another without departing from the scope of the claims. In other words, unless a specific order of steps or actions is specified, the order and/or use of specific steps and/or actions may be modified without departing from the scope of the claims.

The functions described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in hardware, an example hardware configuration may comprise a processing system in a wireless node. The processing system may be implemented with a bus architecture. The bus may include any number of interconnecting buses and bridges depending on the specific application of the processing system and the overall design constraints. The bus may link together various circuits including a processor, machine-readable media, and a bus interface. The bus interface may be used to connect a network adapter, among other things, to the processing system via the bus. The network adapter may be used to implement the signal processing functions of the PHY layer. In the case of a user terminal **120** (see FIG. **1**), a user interface (e.g., keypad, display, mouse, joystick, etc.) may also be connected to the bus. The bus may also link various other circuits such as timing sources, peripherals, voltage regulators, power management circuits, and the like, which are well known in the art, and therefore, will not be described any further.

The processor may be responsible for managing the bus and general processing, including the execution of software stored on the machine-readable media. The processor may be implemented with one or more general-purpose and/or special-purpose processors. Examples include microprocessors, microcontrollers, DSP processors, and other circuitry that can execute software. Software shall be construed broadly to mean instructions, data, or any combination thereof, whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise. Machine-readable media may include, by way of example, RAM (Random Access Memory), flash memory, ROM (Read Only Memory), PROM (Programmable Read-Only Memory), EPROM (Erasable Programmable Read-Only Memory), EEPROM (Electrically Erasable Programmable Read-Only Memory), registers, magnetic disks, optical disks, hard drives, or any other suitable storage medium, or any combination thereof. The machine-readable media may be embodied in a computer-program product. The computer-program product may comprise packaging materials.

In a hardware implementation, the machine-readable media may be part of the processing system separate from the processor. However, as those skilled in the art will readily appreciate, the machine-readable media, or any portion thereof, may be external to the processing system. By way of example, the machine-readable media may include a transmission line, a carrier wave modulated by data, and/or a computer product separate from the wireless node, all which may be accessed by the processor through the bus interface. Alternatively, or in addition, the machine-readable media, or any portion thereof, may be integrated into the processor, such as the case may be with cache and/or general register files.

The processing system may be configured as a general-purpose processing system with one or more microprocessors providing the processor functionality and external memory providing at least a portion of the machine-readable media, all linked together with other supporting circuitry through an external bus architecture. Alternatively, the processing system may be implemented with an ASIC (Application Specific

Integrated Circuit) with the processor, the bus interface, the user interface in the case of an access terminal), supporting circuitry, and at least a portion of the machine-readable media integrated into a single chip, or with one or more FPGAs (Field Programmable Gate Arrays), PLDs (Programmable Logic Devices), controllers, state machines, gated logic, discrete hardware components, or any other suitable circuitry, or any combination of circuits that can perform the various functionality described throughout this disclosure. Those skilled in the art will recognize how best to implement the described functionality for the processing system depending on the particular application and the overall design constraints imposed on the overall system.

The machine-readable media may comprise a number of software modules. The software modules include instructions that, when executed by the processor, cause the processing system to perform various functions. The software modules may include a transmission module and a receiving module. Each software module may reside in a single storage device or be distributed across multiple storage devices. By way of example, a software module may be loaded into RAM from a hard drive when a triggering event occurs. During execution of the software module, the processor may load some of the instructions into cache to increase access speed. One or more cache lines may then be loaded into a general register file for execution by the processor. When referring to the functionality of a software module below, it will be understood that such functionality is implemented by the processor when executing instructions from that software module.

If implemented in software, the functions may be stored or transmitted over as one or more instructions or code on a computer-readable medium. Computer-readable media include both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage medium may be any available medium that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM, or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared (IR), radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, include compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk, and Blu-ray® disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Thus, in some aspects computer-readable media may comprise non-transitory computer-readable media (e.g., tangible media). In addition, for other aspects computer-readable media may comprise transitory computer-readable media (e.g., a signal). Combinations of the above should also be included within the scope of computer-readable media.

Thus, certain aspects may comprise a computer program product for performing the operations presented herein. For example, such a computer program product may comprise a computer-readable medium having instructions stored (and/or encoded) thereon, the instructions being executable by one or more processors to perform the operations described herein. For certain aspects, the computer program product may include packaging material.

Further, it should be appreciated that modules and/or other appropriate means for performing the methods and techniques described herein can be downloaded and/or otherwise obtained by a user terminal and/or base station as applicable. For example, such a device can be coupled to a server to facilitate the transfer of means for performing the methods described herein. Alternatively, various methods described herein can be provided via storage means (e.g., RAM, ROM, a physical storage medium such as a compact disc (CD) or floppy disk, etc.), such that a user terminal and/or base station can obtain the various methods upon coupling or providing the storage means to the device. Moreover, any other suitable technique for providing the methods and techniques described herein to a device can be utilized.

It is to be understood that the claims are not limited to the precise configuration and components illustrated above. Various modifications, changes, and variations may be made in the arrangement, operation, and details of the methods and apparatus described above without departing from the scope of the claims.

The invention claimed is:

1. A method for wireless communications, comprising:

transmitting, to an apparatus, a first control frame indicating a desired bandwidth for transmitting data to the apparatus;

receiving a second control frame indicating an available bandwidth of the apparatus;

determining a bandwidth for transmitting the data to the apparatus based on the lesser of the available bandwidth and the desired bandwidth; and transmitting the data according to the determined bandwidth, wherein the first control frame comprises a Request to Send (RTS) frame, wherein the RTS frame comprises a Service field having a scrambler initialization seed, and wherein the scrambler initialization seed of the Service field indicates the desired bandwidth.

2. The method of claim **1**, wherein the first control frame comprises a Request to Send (RTS) frame and wherein the RTS frame comprises a legacy frame format according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard.

3. The method of claim **1**, wherein the first control frame comprises a Request to Send (RTS) frame, wherein the RTS frame comprises a legacy frame format according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard, and wherein at least one of:

the RTS frame comprises a legacy preamble according to the IEEE 802.11a amendment,

wherein the legacy preamble comprises a legacy signal (L-SIG) field and wherein a bit of the L-SIG field indicates that the RTS frame indicates the desired bandwidth; or

the RTS frame comprises a Service field having two or more reserved bits according to the IEEE 802.11a amendment, wherein the reserved bits of the Service field indicate the desired Bandwidth.

4. The method of claim **3**, wherein at least one of an in-phase (I) component or a quadrature (Q) component of the L-SIG field indicates that the RTS frame indicates the desired bandwidth.

5. The method of claim **1**, wherein the first control frame comprises a Request to Send (RTS) frame, wherein the RTS frame comprises a duration field, and wherein two or more least significant bits (LSBs) of the duration field indicate the desired bandwidth.

6. The method of claim 5, wherein at least one most significant bit (MSB) of the duration field indicates that the RTS frame indicates the desired bandwidth.

7. The method of claim 1, wherein the first control frame comprises a Request to Send (RTS) frame, wherein the RTS frame comprises a frame control field, and wherein two or more bits of the frame control field indicate the desired bandwidth.

8. The method of claim 1, wherein the first control frame comprises a Request to Send (RTS) frame and wherein the RTS frame comprises:

a preamble indicating whether a duplicate mode is used for a data portion of the RTS frame; and

channel bandwidth bits indicating the desired bandwidth.

9. The method of claim 8, wherein the preamble comprises a Very High Throughput Signal A (VHT-SIG-A) field having reserved bits and wherein one of the reserved bits of the VHT-SIG-A field indicates the duplicate mode.

10. The method of claim 1, wherein the first control frame comprises a Request to Send (RTS) frame, wherein the RTS frame comprises a High Throughput Control (HTC) field, and wherein two or more bits of the HTC field indicate the desired bandwidth.

11. The method of claim 1, wherein the first control frame comprises a Request to Send (RTS) frame, wherein the second control frame comprises a Clear to Send (CTS) frame, and wherein the RTS frame comprises a duration field indicating a Network Allocation Vector (NAV) covering reception of the CTS frame, time for a short interframe space (SIPS), and transmission of the data.

12. The method of claim 1, wherein the first control frame comprises a Request to Send (RTS) frame and wherein the RTS frame comprises a frame format with a bandwidth information field indicating the desired bandwidth.

13. The method of claim 12, wherein the RTS frame comprises:

the frame format with the bandwidth information field; and

a legacy preamble according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11 a amendment to the IEEE 802.11 standard or a preamble indicating whether a duplicate mode is used for a data portion of the RTS frame.

14. The method of claim 12, wherein transmitting the first control frame comprises transmitting the RTS frame, with the bandwidth information field, on each of one or more channels for transmitting the data to the apparatus according to the desired bandwidth and wherein receiving the second control frame comprises receiving a Clear to Send (CTS) frame on each of at least a portion of the channels according to the available bandwidth of the apparatus.

15. The method of claim 14, further comprising:

transmitting, to the apparatus, a legacy RTS frame according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard, the legacy RTS frame being duplicated on each of the at least the portion of the channels; and

receiving a legacy CTS frame according to the IEEE 802.11a amendment, the legacy CTS frame being duplicated on each of the at least the portion of the channels, wherein a first Network Allocation Vector (NAV) set by the legacy RTS and legacy CTS frames protects transmission of the data.

16. The method of claim 15, wherein the RTS frame comprises a duration field indicating a second Network Allocation Vector (NAV) covering reception of the CTS frame, time for a short interframe space (SIPS), and transmission of the legacy RTS frame.

17. The method of claim 12, further comprising:

transmitting, to the apparatus, a legacy RTS frame according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard on a primary channel or duplicated on each of a first set of channels; and

receiving a legacy a Clear to Send (CTS) frame according to the IEEE 802.11a amendment on at least a portion of the first set of channels, wherein the at least the portion of the first set of channels are idle at the apparatus, wherein transmitting the first control frame comprises, after receiving the legacy CTS frame, transmitting the RTS frame, with the bandwidth information field, on each of a second set of channels for transmitting the data to the apparatus according to the desired bandwidth, and wherein receiving the second control frame comprises receiving a CTS frame on each of at least a portion of the second set of channels according to the available bandwidth of the apparatus.

18. An apparatus for wireless communications, comprising:

a transmitter configured to transmit, to another apparatus, a first control frame indicating a desired bandwidth for transmitting data to the other apparatus; and

a receiver configured to receive a second control frame indicating an available bandwidth of the other apparatus; and

a processor configured to determine a bandwidth for transmitting the data to the another apparatus based on the lesser of the available bandwidth and the desired bandwidth, wherein the transmitter is further configured to transmit the data at the determined bandwidth, wherein the first control frame comprises a Request to Send (RTS) frame, and wherein the RTS frame comprises a Service field having a scrambler initialization seed, and wherein the scrambler initialization seed of the Service field indicates the desired bandwidth.

19. The apparatus of claim 18, wherein the first control frame comprises a Request to Send (RTS) frame and wherein the RTS frame comprises a legacy frame format according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard.

20. The apparatus of claim 18, wherein the first control frame comprises a Request to Send (RTS) frame, wherein the RTS frame comprises a legacy frame format according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard, and wherein at least one of:

the RTS frame comprises a legacy preamble according to the IEEE 802.11a amendment, wherein the legacy preamble comprises a legacy signal (L-SIG) field and wherein a bit of the L-SIG field indicates that the RTS frame indicates the desired bandwidth; or

the RTS frame comprises a Service field having two or more reserved bits according to the IEEE 802.11a amendment, wherein the reserved bits of the Service field indicate the desired bandwidth.

21. The apparatus of claim 20, wherein at least one of an in-phase (I) component or a quadrature (Q) component of the L-SIG field indicates that the RTS frame indicates the desired bandwidth.

22. The apparatus of claim 18, wherein the first control frame comprises a Request to Send (RTS) frame, wherein the RTS frame comprises a duration field, and wherein two or more least significant bits (LSBs) of the duration field indicate the desired bandwidth.

23. The apparatus of claim 22, wherein at least one most significant bit (MSB) of the duration field indicates that the RTS frame indicates the desired bandwidth.

24. The apparatus of claim 18, wherein the first control frame comprises a Request to Send (RTS) frame, wherein the RTS frame comprises a frame control field, and wherein two or more bits of the frame control field indicate the desired bandwidth.

25. The apparatus of claim 18, wherein the first control frame comprises a Request to Send (RTS) frame and wherein the RTS frame comprises:

a preamble indicating whether a duplicate mode is used for a data portion of the RTS frame; and

channel bandwidth bits indicating the desired bandwidth.

26. The apparatus of claim 25, wherein the preamble comprises a Very High Throughput Signal A (VHT-SIG-A) field having reserved bits and wherein one of the reserved bits of the VHT-SIG-A field indicates the duplicate mode.

27. The apparatus of claim 18, wherein the first control frame comprises a Request to Send (RTS) frame, wherein the RTS frame comprises a High Throughput Control (HTC) field, and wherein two or more bits of the HTC field indicate the desired bandwidth.

28. The apparatus of claim 18, wherein the first control frame comprises a Request to Send (RTS) frame, wherein the second control frame comprises a Clear to Send (CTS) frame, and wherein the RTS frame comprises a duration field indicating a Network Allocation Vector (NAV) covering reception of the CTS frame, time for a short interframe space (SIPS), and transmission of the data.

29. The apparatus of claim 18, wherein the first control frame comprises a Request to Send (RTS) frame and wherein the RTS frame comprises a frame format with a bandwidth information field indicating the desired bandwidth.

30. The apparatus of claim 29, wherein the RTS frame comprises:

the frame format with the bandwidth information field; and

a legacy preamble according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11 a amendment to the IEEE 802.11 standard or a preamble indicating whether a duplicate mode is used for a data portion of the RTS frame.

31. The apparatus of claim 29, wherein the transmitter is configured to transmit the first control frame by transmitting the RTS frame, with the bandwidth information field, on each of one or more channels for transmitting the data to the other apparatus according to the desired bandwidth and wherein the receiver is configured to receive the second control frame by receiving a Clear to Send (CTS) frame on each of at least a portion of the channels according to the available bandwidth of the other apparatus.

32. The apparatus of claim 31, wherein the transmitter is further configured to transmit, to the other apparatus, a legacy RTS frame according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard, the legacy RTS frame being duplicated on each of the at least the portion of the channels; and wherein the receiver is further configured to receive a legacy CTS frame according to the IEEE 802.11a amendment, the legacy CTS frame being duplicated on each of the at least the portion of the channels, wherein a first Network Allocation Vector (NAV) set by the legacy RTS and legacy CTS frames protects transmission of the data.

33. The apparatus of claim 32, wherein the RTS frame comprises a duration field indicating a second Network Allocation Vector (NAV) covering reception of the CTS frame, time for a short interframe space (SIPS), and transmission of the legacy RTS frame.

34. The apparatus of claim 29, wherein the transmitter is further configured to transmit, to the other apparatus, a legacy RTS frame according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard on a primary channel or duplicated on each of a first set of channels; wherein the receiver is further configured to receive a legacy Clear to Send (CTS) frame according to the IEEE 802.11a amendment on at least a portion of the first set of channels, wherein the at least the portion of the first set of channels are idle at the other apparatus; wherein the transmitter is further configured to transmit the first control frame by, after receiving the legacy CTS frame, transmitting the RTS frame, with the bandwidth information field, on each of a second set of channels for transmitting the data to the other apparatus according to the desired bandwidth; and wherein the receiver is further configured to receive the second control frame by receiving a CTS frame on each of at least a portion of the second set of channels according to the available bandwidth of the other apparatus.

35. An apparatus for wireless communications, comprising:

means for transmitting, to another apparatus, a first control frame indicating a desired bandwidth for transmitting data to the other apparatus;

means for receiving a second control frame indicating an available bandwidth of the other apparatus; and

means for determining a bandwidth for transmitting the data to the apparatus based on the lesser of the available bandwidth and the desired bandwidth, wherein the means for transmitting is further configured to transmit the data at the determined bandwidth, wherein the first control frame comprises a Request to Send (RTS) frame, wherein the RTS frame comprises a Service field having a scrambler initialization seed, and wherein the scrambler initialization seed of the Service field indicates the desired bandwidth.

36. The apparatus of claim 35, wherein the first control frame comprises a Request to Send (RTS) frame and wherein the RTS frame comprises a legacy frame format according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard.

37. The apparatus of claim 35, wherein the first control frame comprises a Request to Send (RTS) frame, wherein the RTS frame comprises a legacy frame format according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard, and wherein at least one of:

the RTS frame comprises a legacy preamble according to the IEEE 802.11a amendment, wherein the legacy preamble comprises a legacy signal (L-SIG) field and wherein a bit of the L-SIG field indicates that the RTS frame indicates the desired bandwidth; or

the RTS frame comprises a Service field having two or more reserved bits according to the IEEE 802.11a amendment, wherein the reserved bits of the Service field indicate the desired bandwidth.

38. The apparatus of claim 37, wherein at least one of an in-phase (I) component or a quadrature (Q) component of the L-SIG field indicates that the RTS frame indicates the desired bandwidth.

39. The apparatus of claim 35, wherein the first control frame comprises a Request to Send (RTS) frame, wherein the

RTS frame comprises a duration field, and wherein two or more least significant bits (LSBs) of the duration field indicate the desired bandwidth.

40. The apparatus of claim **39**, wherein at least one most significant bit (MSB) of the duration field indicates that the RTS frame indicates the desired bandwidth.

41. The apparatus of claim **35**, wherein the first control frame comprises a Request to Send (RTS) frame, wherein the RTS frame comprises a frame control field, and wherein two or more bits of the frame control field indicate the desired bandwidth.

42. The apparatus of claim **35**, wherein the first control frame comprises a Request to Send (RTS) frame and wherein the RTS frame comprises:

a preamble indicating whether a duplicate mode is used for a data portion of the RTS frame; and

channel bandwidth bits indicating the desired bandwidth.

43. The apparatus of claim **42**, wherein the preamble comprises a Very High Throughput Signal A (VHT-SIG-A) field having reserved bits and wherein one of the reserved bits of the VHT-SIG-A field indicates the duplicate mode.

44. The apparatus of claim **35**, wherein the first control frame comprises a Request to Send (RTS) frame, wherein the RTS frame comprises a High Throughput Control (HTC) field, and wherein two or more bits of the HTC field indicate the desired bandwidth.

45. The apparatus of claim **35**, wherein the first control frame comprises a Request to Send (RTS) frame, wherein the second control frame comprises a Clear to Send (CTS) frame, and wherein the RTS frame comprises a duration field indicating a Network Allocation Vector (NAV) covering reception of the CTS frame, time for a short interframe space (SIPS), and transmission of the data.

46. The apparatus of claim **35**, wherein the first control frame comprises a Request to Send (RTS) frame and wherein the RTS frame comprises a frame format with a bandwidth information field indicating the desired bandwidth.

47. The apparatus of claim **46**, wherein the RTS frame comprises:

the frame format with the bandwidth information field; and

a legacy preamble according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11 a amendment to the IEEE 802.11 standard or a preamble indicating whether a duplicate mode is used for a data portion of the RTS frame.

48. The apparatus of claim **46**, wherein the means for transmitting the first control frame is configured to transmit the RTS frame, with the bandwidth information field, on each of one or more channels for transmitting the data to the other apparatus according to the desired bandwidth and wherein the means for receiving the second control frame is configured to receive a Clear to Send (CTS) frame on each of at least a portion of the channels according to the available bandwidth of the other apparatus.

49. The apparatus of claim **48**, wherein the means for transmitting IS further configured to transmit, to the other apparatus, a legacy RTS frame according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard, the legacy RTS frame being duplicated on each of the at least the portion of the channels; and wherein the means for receiving is further configured to receive a legacy CTS frame according to the IEEE 802.11a amendment, the legacy CTS frame being duplicated on each of the at least the portion of the channels, wherein a first Network Allocation Vector (NAV) set by the legacy RTS and legacy CTS frames protects transmission of the data.

50. The apparatus of claim **49**, wherein the RTS frame comprises a duration field indicating a second Network Allocation Vector (NAV) covering reception of the CTS frame, time for a short interframe space (SIPS), and transmission of the legacy RTS frame.

51. The apparatus of claim **46**, wherein the means for transmitting IS further configured to transmit, to the other apparatus, a legacy RTS frame according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard on a primary channel or duplicated on each of a first set of channels; wherein the means for receiving is further configured to receive a legacy Clear to Send (CTS) frame according to the IEEE 802.11a amendment on at least a portion of the first set of channels, wherein the at least the portion of the first set of channels are idle at the other apparatus; wherein the means for transmitting the first control frame is further configured to, after receiving the legacy CTS frame, transmit the RTS frame, with the bandwidth information field, on each of a second set of channels for transmitting the data to the other apparatus according to the desired bandwidth; and wherein the means for receiving the second control frame is further configured to receive a CTS frame on each of at least a portion of the second set of channels according to the available bandwidth of the other apparatus.

52. A non-transitory computer-readable medium comprising instructions executable to:

transmit, to an apparatus, a first control frame indicating a desired bandwidth for transmitting data to the apparatus;

receive a second control frame indicating an available bandwidth of the apparatus;

determine a bandwidth for transmitting the data to the apparatus based on the lesser of the available bandwidth and the desired bandwidth; and

transmit the data at the determined bandwidth, wherein the first control frame comprises a Request to Send (RTS) frame, wherein the RTS frame comprises a Service field having a scrambler initialization seed, and wherein the scrambler initialization seed of the Service field indicates the desired bandwidth.

53. An access point, comprising:

at least one antenna;

a transmitter configured to transmit, to an apparatus via the at least one antenna, a first control frame indicating a desired bandwidth for transmitting data to the apparatus; and

a receiver configured to receive a second control frame indicating an available bandwidth of the apparatus; and

a processor configured to determine a bandwidth for transmitting the data to the apparatus based on the lesser of the available bandwidth and the desired bandwidth, wherein the transmitter is further configured to transmit the data at the determined bandwidth, wherein the first control frame comprises a Request to Send (RTS) frame, wherein the RTS frame comprises a Service field having a scrambler initialization seed, and wherein the scrambler initialization seed of the Service field indicates the desired bandwidth.

54. A method for wireless communications, comprising:

receiving, at an apparatus, from another apparatus, a first control frame indicating a desired bandwidth for sending data to the apparatus;

in response to receiving the first control frame, transmitting a second control frame indicating an available bandwidth of the apparatus; and

receiving the data at a bandwidth that is the lesser of the available bandwidth and the desired bandwidth,

wherein the first control frame comprises a Request to Send (RTS) frame, and wherein the RTS frame comprises a Service field having a scrambler initialization seed, and wherein the scrambler initialization seed of the Service field indicates the desired bandwidth.

55. The method of claim **54**, wherein the second control frame comprises a Clear to Send (CTS) frame and wherein the CTS frame comprises a legacy frame format according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard.

56. The method of claim **54**, wherein the second control frame comprises a Clear to Send (CTS) frame, wherein the CTS frame comprises a legacy frame format according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard, and wherein at least one of:

the CTS frame comprises a legacy preamble according to the IEEE 802.11a amendment, wherein the legacy preamble comprises a legacy signal (L-SIG) field and wherein a bit of the L-SIG field indicates that the CTS frame indicates the available bandwidth; or

the CTS frame comprises a Service field having two or more reserved bits according to the IEEE 802.11a amendment, wherein the reserved bits of the Service field indicate the available bandwidth.

57. The method of claim **56**, wherein at least one of an in-phase (I) component or a quadrature (Q) component of the L-SIG field indicates that the CTS frame indicates the available bandwidth.

58. The method of claim **54**, wherein the second control frame comprises a Clear to Send (CTS) frame, wherein the CTS frame comprises a duration field, and wherein two or more least significant bits (LSBs) of the duration field indicate the available bandwidth.

59. The method of claim **58**, wherein at least one most significant bit (MSB) of the duration field indicates that the CTS frame indicates the available bandwidth.

60. The method of claim **54**, wherein the second control frame comprises a Clear to Send (CTS) frame, wherein the CTS frame comprises a frame control field, and wherein two or more bits of the frame control field indicate the available bandwidth.

61. The method of claim **54**, wherein the second control frame comprises a Clear to Send (CTS) frame and wherein the CTS frame comprises:

a preamble indicating whether a duplicate mode is used for a data portion of the CTS frame; and

channel bandwidth bits indicating the available bandwidth.

62. The method of claim **61**, wherein the preamble comprises a Very High Throughput Signal A (VHT-SIG-A) field having reserved bits and wherein one of the reserved bits of the VHT-SIG-A field indicates the duplicate mode.

63. The method of claim **54**, wherein the second control frame comprises a Clear to

Send (CTS) frame, wherein the CTS frame comprises a High Throughput Control (HTC) field, and wherein two or more bits of the HTC field indicate the available bandwidth.

64. The method of claim **54**, wherein the second control frame comprises a Clear to Send (CTS) frame and wherein the CTS frame comprises a frame format with a bandwidth information field indicating the available bandwidth.

65. The method of claim **64**, wherein the CTS frame comprises a legacy preamble according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard or a preamble indicating whether a duplicate mode is used for a data portion of the CTS frame.

66. The method of claim **64**, wherein receiving the first control frame comprises receiving a Request to Send (RTS) frame on each of one or more channels for sending the data to the apparatus according to the desired bandwidth and wherein transmitting the second control frame comprises transmitting the CTS frame, with the bandwidth information field, on each of at least a portion of the channels according to the available bandwidth of the apparatus.

67. The method of claim **66**, further comprising:

receiving, at the apparatus, a legacy RTS frame according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard, the legacy RTS frame duplicated on each of the at least the portion of the channels; and

transmitting a legacy CTS frame according to the IEEE 802.11 a amendment, the legacy CTS frame being duplicated on each of the at least the portion of the channels, wherein a Network Allocation Vector (NAV) set by the legacy RTS and legacy CTS frames protects reception of the data.

68. The method of claim **64**, further comprising:

receiving, at the apparatus, a legacy Request to Send (RTS) frame according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard, the legacy RTS frame received on a primary channel or duplicated on each of a first set of channels; and

transmitting a legacy CTS frame according to the IEEE 802.IIa amendment on at least a portion of the first set of channels, wherein the at least the portion of the first set of channels are idle at the apparatus, wherein receiving the first control frame comprises, after transmitting the legacy CTS frame, receiving a RTS frame on each of a second set of channels for sending the data to the apparatus according to the desired bandwidth, and wherein transmitting the second control frame comprises transmitting the CTS frame, with the bandwidth information field, on each of at least a portion of the second set of channels according to the available bandwidth of the apparatus.

69. The method of claim **54**, further comprising checking whether an address of the first control frame corresponds to a multichannel-capable entity before determining the desired bandwidth from the received first control frame, wherein the checking is based on the address belonging to a set of addresses.

70. An apparatus for wireless communications, comprising:

a receiver configured to receive, from another apparatus, a first control frame indicating a desired bandwidth for sending data to the apparatus; and

a transmitter configured to transmit, in response to receiving the first control frame, a second control frame indicating an available bandwidth of the apparatus,

wherein the receiver is further configured to receive the data at a bandwidth that is the lesser of the available bandwidth and the desired bandwidth, wherein the first control frame comprises a Request to Send (RTS) frame, and wherein the RTS frame comprises a Service field having a scrambler initialization seed, and wherein the scrambler initialization seed of the Service field indicates the desired bandwidth.

71. The apparatus of claim **70**, wherein the second control frame comprises a Clear to Send (CTS) frame and wherein the CTS frame comprises a legacy frame format according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard.

72. The apparatus of claim 70, wherein the second control frame comprises a Clear to Send (CTS) frame, wherein the CTS frame comprises a legacy frame format according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard, and wherein at least one of:

the CTS frame comprises a legacy preamble according to the IEEE 802.11a amendment, wherein the legacy preamble comprises a legacy signal (L-SIG) field and wherein a bit of the L-SIG field indicates that the CTS frame indicates the available bandwidth; or

the CTS frame comprises a Service field having two or more reserved bits according to the IEEE 802.11a amendment, wherein the reserved bits of the Service field indicate the available bandwidth.

73. The apparatus of claim 72, wherein at least one of an in-phase (I) component or a

quadrature (Q) component of the L-SIG field indicates that the CTS frame indicates the available bandwidth.

74. The apparatus of claim 70, wherein the second control frame comprises a Clear to Send (CTS) frame, wherein the CTS frame comprises a duration field, and wherein two or more least significant bits (LSBs) of the duration field indicate the available bandwidth.

75. The apparatus of claim 74, wherein at least one most significant bit (MSB) of the duration field indicates that the CTS frame indicates the available bandwidth.

76. The apparatus of claim 70, wherein the second control frame comprises a Clear to Send (CTS) frame, wherein the CTS frame comprises a frame control field, and wherein two or more bits of the frame control field indicate the available bandwidth.

77. The apparatus of claim 70, wherein the second control frame comprises a Clear toSend (CTS) frame and wherein the CTS frame comprises:

a preamble indicating whether a duplicate mode is used for a data portion of the CTS frame; and

channel bandwidth bits indicating the available bandwidth.

78. The apparatus of claim 77, wherein the preamble comprises a Very High Throughput Signal A (VHT-SIG-A) field having reserved bits and wherein one of the reserved bits of the VHT-SIG-A field indicates the duplicate mode.

79. The apparatus of claim 70, wherein the second control frame comprises a Clear to Send (CTS) frame, wherein the CTS frame comprises a High Throughput Control (HTC) field, and wherein two or more bits of the HTC field indicate the available bandwidth.

80. The apparatus of claim 70, wherein the second control frame comprises a Clear to Send (CTS) frame and wherein the CTS frame comprises a frame format with a bandwidth information field indicating the available bandwidth.

81. The apparatus of claim 80, wherein the CTS frame comprises a legacy preamble according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard or a preamble indicating whether a duplicate mode is used for a data portion of the CTS frame.

82. The apparatus of claim 80, wherein the receiver is configured to receive the first control frame by receiving a Request to Send (RTS) frame on each of one or more channels for sending the data to the apparatus according to the desired bandwidth and wherein the transmitter is configured to transmit the second control frame by transmitting the CTS frame, with the bandwidth information field, on each of at least a portion of the channels according to the available bandwidth of the apparatus.

83. The apparatus of claim 82, wherein the receiver is further configured to receive a legacy RTS frame according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11 a amendment to the IEEE 802.11 standard, the legacy RTS frame duplicated on each of the at least the portion of the channels; and wherein the transmitter is further configured to transmit a legacy CTS frame according to the IEEE 802.11a amendment, the legacy CTS frame being duplicated on each of the at least the portion of the channels, wherein a Network Allocation Vector (NAV) set by the legacy RTS and legacy CTS frames protects reception of the data.

84. The apparatus of claim 80, wherein the receiver is further configured to receive a legacy Request to Send (RTS) frame according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard, the legacy RTS frame received on a primary channel or duplicated on each of a first set of channels; wherein the transmitter is further configured to transmit a legacy CTS frame according to the IEEE 802.11a amendment on at least a portion of the first set of channels, wherein the at least the portion of the first set of channels are idle at the apparatus; wherein the receiver is further configured to receive the first control frame by, after transmitting the legacy CTS frame, receiving a RTS frame on each of a second set of channels for sending the data to the apparatus according to the desired bandwidth; and wherein the transmitter is further configured to transmit the second control frame by transmitting the CTS frame, with the bandwidth information field, on each of at least a portion of the second set of channels according to the available bandwidth of the apparatus.

85. The apparatus of claim 70, further comprising a processing system configured to check whether an address of the first control frame corresponds to a multichannel-capable entity before determining the desired bandwidth from the received first control frame, wherein the checking is based on the address belonging to a set of addresses.

86. An apparatus for wireless communications, comprising:

a means for receiving, from another apparatus, a first control frame indicating a desired bandwidth for sending data to the apparatus; and

a means for transmitting, in response to receiving the first control frame, a second control frame indicating an available bandwidth of the apparatus,

wherein the means for receiving is further configured to receive the data at a bandwidth that is the lesser of the available bandwidth and the desired bandwidth, wherein the first control frame comprises a Request to Send (RTS) frame, and wherein the RTS frame comprises a Service field having a scrambler initialization seed, and wherein the scrambler initialization seed of the Service field indicates the desired bandwidth.

87. The apparatus of claim 86, wherein the second control frame comprises a Clear to Send (CTS) frame and wherein the CTS frame comprises a legacy frame format according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard.

88. The apparatus of claim 86, wherein the second control frame comprises a Clear to Send (CTS) frame, wherein the CTS frame comprises a legacy frame format according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard, and wherein at least one of:

the CTS frame comprises a legacy preamble according to the IEEE 802.11a amendment, wherein the legacy preamble comprises a legacy signal (L-SIG) field and

wherein a bit of the L-SIG field indicates that the CTS frame indicates the available bandwidth; or

the CTS frame comprises a Service field having two or more reserved bits according to the IEEE 802.11a amendment, wherein the reserved bits of the Service field indicate the available bandwidth.

89. The apparatus of claim **88**, wherein at least one of an in-phase (I) component or a quadrature (Q) component of the L-SIG field indicates that the CTS frame indicates the available bandwidth.

90. The apparatus of claim **86**, wherein the second control frame comprises a Clear to Send (CTS) frame, wherein the CTS frame comprises a duration field, and wherein two or more least significant bits (LSBs) of the duration field indicate the available bandwidth.

91. The apparatus of claim **90**, wherein at least one most significant bit (MSB) of the duration field indicates that the CTS frame indicates the available bandwidth.

92. The apparatus of claim **86**, wherein the second control frame comprises a Clear to Send (CTS) frame, wherein the CTS frame comprises a frame control field, and wherein two or more bits of the frame control field indicate the available bandwidth.

93. The apparatus of claim **86**, wherein the second control frame comprises a Clear to Send (CTS) frame and wherein the CTS frame comprises:

a preamble indicating whether a duplicate mode is used for a data portion of the CTS frame; and

channel bandwidth bits indicating the available bandwidth.

94. The apparatus of claim **93**, wherein the preamble comprises a Very High Throughput Signal A (VHT-SIG-A) field having reserved bits and wherein one of the reserved bits of the VHT-SIG-A field indicates the duplicate mode.

95. The apparatus of claim **86**, wherein the second control frame comprises a Clear to Send (CTS) frame, wherein the CTS frame comprises a High Throughput Control (HTC) field, and wherein two or more bits of the HTC field indicate the available bandwidth.

96. The apparatus of claim **86**, wherein the second control frame comprises a Clear to Send (CTS) frame and wherein the CTS frame comprises a frame format with a bandwidth information field indicating the available bandwidth.

97. The apparatus of claim **96**, wherein the CTS frame comprises a legacy preamble according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard or a preamble indicating whether a duplicate mode is used for a data portion of the CTS frame.

98. The apparatus of claim **96**, wherein the means for receiving the first control frame is configured to receive a Request to Send (RTS) frame on each of one or more channels for sending the data to the apparatus according to the desired bandwidth and wherein the means for transmitting the second control frame is configured to transmit the CTS frame, with the bandwidth information field, on each of at least a portion of the channels according to the available bandwidth of the apparatus.

99. The apparatus of claim **98**, wherein the means for receiving is further configured to receive a legacy RTS frame according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard, the legacy RTS frame duplicated on each of the at least the portion of the channels; and wherein the means for transmitting is further configured to transmit a legacy CTS frame according to the IEEE 802.11a amendment, the legacy CTS frame being duplicated on each of the at least the portion of the channels, wherein a Network Allocation Vector (NAV) set by the legacy RTS and legacy CTS frames protects reception of the data.

100. The apparatus of claim **96**, wherein the means for receiving is further configured to receive a legacy Request to Send (RTS) frame according to the Institute of Electrical and Electronics Engineers (IEEE) 802.11a amendment to the IEEE 802.11 standard, the legacy RTS frame received on a primary channel or duplicated on each of a first set of channels; wherein the means for transmitting is further configured to transmit a legacy CTS frame according to the IEEE 802.11a amendment on at least a portion of the first set of channels, wherein the at least the portion of the first set of channels are idle at the apparatus; wherein the means for receiving the first control frame is further configured to, after transmitting the legacy CTS frame, receive a RTS frame on each of a second set of channels for sending the data to the apparatus according to the desired bandwidth; and wherein the means for transmitting the second control frame is further configured to transmit the CTS frame, with the bandwidth information field, on each of at least a portion of the second set of channels according to the available bandwidth of the apparatus.

101. The apparatus of claim **86**, further comprising means for checking whether an address of the first control frame corresponds to a multichannel-capable entity before determining the desired bandwidth from the received first control frame, wherein the checking is based on the address belonging to a set of addresses.

102. A non-transitory computer-readable medium comprising instructions executable to:

receive, at an apparatus from another apparatus, a first control frame indicating a desired bandwidth for sending data to the apparatus;

transmit, in response to receiving the first control frame, a second control frame indicating an available bandwidth of the apparatus; and

receive the data at a bandwidth that is the lesser of the available bandwidth and the desired bandwidth,

wherein the first control frame comprises a Request to Send (RTS) frame, and wherein the RTS frame comprises a Service field having a scrambler initialization seed, and wherein the scrambler initialization seed of the Service field indicates the desired bandwidth.

103. A wireless node, comprising:

at least one antenna;

a receiver configured to receive from another apparatus, via the at least one antenna, a first control frame indicating a desired bandwidth for sending data to the wireless node; and

a transmitter configured to transmit, in response to receiving the first control frame, a second control frame indicating an available bandwidth of the wireless node,

wherein the receiver is further configured to receive the data at a bandwidth that is the lesser of the available bandwidth and the desired bandwidth, wherein the first control frame comprises a Request to Send (RTS) frame, and wherein the RTS frame comprises a Service field having a scrambler initialization seed, and wherein the scrambler initialization seed of the Service field indicates the desired bandwidth.

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